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THE GERM CELL CYCLE IN THE DIGENETIC TREMATODES

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OUTLINE OF LIFE CYCLE IN THE DIGENETIC TREMATODES

IN THE life cycle of the trematodes the vertebrate-dwelling adults have ovaries and testes in which are produced ova and spermatozoa. Spermatogenesis, oogenesis and fertilization are not fundamentally different from these processes in other metazoan groups (for review of the literature see Cable, 1931; Chen, 1937; Rees, 1939). The fertilized ovum is enclosed in a shell, and is surrounded by yolk cells which provide food for the developing embryo. In the digenetic trematodes, which have an alternation of generations, this embryo becomes the miracidium, which after entering the molluscan intermediate host metamorphoses into a primary germinal sac, the mother sporocyst. Inside the mother sporocyst develop secondary germinal sacs, the rediae or daughter sporocysts. The presence of a digestive system distinguishes rediae from daughter sporocysts and these stages have never been found in the same life cycle. There may be either one or two generations of rediae, but when the secondary germinal sacs are daughter sporocysts only one generation has been found. Finally, in the secondary germinal sacs cercariae are produced, which after reaching the definitive host develop into the adults. The cercariae usually escape from the intermediate host and have a brief period of free life. Their method of reaching the definitive host varies greatly in different groups. They may encyst in the open (the sheep liver fluke), penetrate directly into the definitive host (the schistosomes), or encyst in a second intermediate host (the human liver or lung flukes). With such complicated life cycles frequently involving three hosts, the hazards are very great, and there is an enormous loss of individuals. Therefore, digenetic trematodes usually have an extraordinary reproductive activity both in the production of enormous numbers of eggs by the adults and of large numbers of cercariae by the germinal sacs in the intermediate host. There is some evidence that in a few cases cercariae may develop directly in the primary germinal sacs. Therefore, in the different groups of the digenetic trematodes the life cycle may be an alternation of two, three or four generations. The first generation always begins with the fertilized ovum and includes the miracidium and the primary germinal sac, the mother sporocyst; and the last generation always includes the cercariae and adults.

METHODS OF REPRODUCTION IN GERMINAL SACS

Ever since Steenstrup in 1842 first outlined the theory of alternation of generations of the digenetic trematodes, the method of reproduction in the germinal sacs in the intermediate host has been a subject of controversy. Steenstrup and several of the earlier workers considered this alternation of generations to be a metagenesis. According to this view, reproduction in the sporocysts and rediae is an asexual process of internal budding.

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Later, the finding of specific reproductive cells enclosed in the germinal sacs caused most workers to discard this view.

Grobben in 1882 first proposed the hypothesis that the alternation of generations of the digenetic trematodes is a heterogeny, and that the reproductive cells in the germinal sacs are true parthenogenetic ova. Later, several workers described and figured the formation of polar bodies by these reproductive cells, and considered that they are produced in definite ovaries or in the walls of the germinal sacs (for a review of the literature on these points see Brooks, 1930). On the other hand, Brooks, and others including the most recent workers on the problem, have been unable to demonstrate polar bodies. They have pointed out that there was no uniformity in the descriptions of the maturation process by the various workers, and that the structures described as polar bodies can be otherwise explained.

Recently Woodhead (1931) has described a very complicated type of sexual reproduction in the germinal sacs of one of the groups of the digenetic trematodes, the Bucephalidae, the members of which have branched mother sporocysts. He described ovaries and testes not only in certain of the mother sporocyst branches but also in a redial generation which he described as parasitic in the sporocyst. According to his view, spermatozoa and mature ova are produced by both the mother sporocyst and redia. He therefore interpreted the life cycle of this group as an alternation of a series of three polymorphic adults, in each of which the reproduction is bisexual.

Quite a different view of the method of reproduction of the sporocysts and rediae was first presented in 1886 by Leuckart, who considered it to represent a "germinal lineage." The germinal lineage hypothesis was revived by Dollfus (1919) and has been supported by the most recent studies on the germ cell cycle of the digenetic trematodes (Brooks, 1930; Cable, 1934; Chen, 1937; Rees, 1940). According to this view, the reproductive cells of the sporocysts and rediae can be traced back directly to the fertilized ovum. Also, these cells of the germinal line never become true germ cells, and remain separate from the soma cells during the development of the reproductive sacs, since they are never localized in reproductive tissues. Therefore, the multiplication of the cells of the germinal line is really a polyembryony of the original zygote (fertilized ovum), extending throughout the whole development of the germinal sacs in the molluscan intermediate host. During this process numerous soma cells are split off from the cells of the germinal line. They form the primary and secondary germinal sacs, which come to contain the multiplying germinal cells and the embryos that develop from them.

These reproductive cells will be referred to in the remainder of this paper as cells of the germinal line, or germinal cells, to distinguish them from true germ cells, which in the life cycle of the digenetic trematodes, if we accept the germinal lineage hypothesis, are only produced in the testes and ovaries of the adults. It should be noted, however, that even in the most recent papers which support the theory of germinal lineage they have been called germ cells.

According to this hypothesis the only cells, either somatic or reproductive, in all the stages of the life cycle of the digenetic trematodes, that have the reduced number of chromosomes are the spermatozoa and mature ova formed by the adult. During the stages in the intermediate host the polyembryony of the germinal cells continues actively and the soma cells produce only germinal sacs. Then when the germinal cells develop into cercarial embryos, they produce the reproductive organs of the adults, in which some cells of the germinal line undergo gametogenesis, producing true germ cells.

Of the papers on the germ cell cycle of digenetic trematodes which support the germinal lineage hypothesis, that of Chen (1937) is the most complete. This author studied the stages of the mammalian lung fluke, *Paragonimus kellicotti*. In the life cycle of this parasite, as shown by Ameel (1934), the fertilized ovum—miracidium—mother sporocyst generation is followed by two generations of rediae, in the second of which the cercariae are produced. Chen first studied oogenesis, spermatogenesis, and fertilization in the adults of this species and found that the diploid number of chromosomes is 16 and the haploid number 8. The fertilized ovum then has 16 chromosomes. She then followed the germinal line through all the stages in the snail intermediate host, ending with the cercaria. In the cleavage of the fertilized ovum inside the egg, the first division gives rise to a propagatory (P) cell and a somatic (S) cell. From this first somatic cell arise the cells which form the outer structure of the miracidium's body. The propagatory cell continues to divide into "P-cells" and "S-cells" and from the latter

the internal organs of the miracidium develop. Finally no more "S-cells" are produced, and the last "P-cell" divides into a group of "germ cells" which lie in the body cavity of the miracidium. Then after the miracidium has entered the intermediate host and metamorphosed into the mother sporocyst, these cells of the germinal line develop into first generation rediae. In the embryonic development of the first generation rediae this process is repeated, and a group of germinal cells comes to lie in the body cavity. These later produce second generation rediae. This process is repeated in these rediae, and the germinal cells that come to lie in their body cavities produce cercariae. Finally, in the development of the cercariae the cells of the germinal line form the genital primordia, from which the genital organs of the adult are produced. The number of chromosomes throughout remains at 16 in the cells of the germinal line, since no reduction divisions occur in the germinal sacs. Only in the formation of the spermatozoa and ova in the adult does reduction take place.

Rees (1940) later followed the germ cell cycle throughout the life cycle of an echinostome species, *Parochis acanthus* Nicoll. The life cycle of this species is very unusual for the echinostomes, since a single first generation redia is produced precociously inside the miracidium. The author was able to trace the cell which produces this redia, from the first cleavage of the fertilized ovum until it started embryonic development. Also, she was able to follow the cells of the germinal line throughout the development of both generations of rediae and to their development of the genital primordium of the cercaria. Her findings agree with those of Chen, and she interprets them as supporting the hypothesis of germinal lineage.

Cable (1934) found the "primordial germ cells" of the young redia of a heterophyid, *Cryptocotyle lingua*, in an undifferentiated condition in the body cavity and stated that they give rise directly to cercarial embryos without undergoing maturation. He also stated that the soma of the redia does not produce "germ cells" at any stage. His work also supports the germinal lineage hypothesis.

The investigations of Brooks (1930) also lend support to the germinal lineage hypothesis. In a study of the cercaria-producing sporocysts and rediae of twenty different species belonging to eight different groups of the digenetic trematodes, he found no structures that could be interpreted as ovaries. Also, no polar bodies or other maturation phenomena of the germinal cells were seen. He found germinal cells lying in the body cavities of very immature daughter sporocysts and rediae, and accounted for germinal multiplication by the successive division of these "antecedent germ cells." According to his interpretations, this is followed by the production from the "antecedent germ cells" of loosely organized "germ-masses," the unicellular components of which separate to produce cercarial embryos. He presents the hypothesis that in the germ cell cycle of the digenetic trematodes "the germinal lineage passes through successive larval stages in which polyembryony features as a mode of multiplication and in which precocious cleavage is an activating factor."

Studies on the development of the miracidium by several other workers also support the germinal lineage hypothesis (Ishii, 1934; and others,—see Rees, 1940, p. 381). Of these, the study of Ishii on the development of the miracidium of *Fasciolopsis buski* is the most complete, since he followed the germinal line throughout the whole embryology. In fact, numerous descriptions of miracidia lend support to this hypothesis, since they show the germinal cells, distinctly separate from the soma, lying in the body cavity. Also, some of the few studies in which very immature mother sporocysts are described show the germinal cells free in the body cavity of the simple sac that has metamorphosed from the miracidium (cf. Talbot, 1933, Fig. 2; Walker, 1939, Figs. 5–10).

The recent studies of the author and his coworkers on living material of very immature mother and daughter sporocysts fit in with the germinal lineage hypothesis. It was found that in the early development of the mother sporocysts of a schistosome, *Schistosomatium douthitti*, the germinal cells of the miracidium come to lie in the body cavity of the very immature mother sporocyst (Cort, Ameel, and Olivier, 1944, Fig. 1). Then after a period of multiplication by direct division which increases their number to about 200, each develops into a daughter sporocyst embryo. Also in very young mother sporocysts of plagiorchiids (Cort and Ameel, 1944, Figs. 1 and 4) numerous germinal cells, which develop directly into daughter sporocyst embryos, are present in the body cavity. Of interest also in this series of studies is the germinal development in the daughter sporocyst embryos. Very immature embryos in the "germ ball" stage already show

the segregation of the cells of the germinal line, since they consist of a group of germinal cells exactly like the cell from which the embryo develops, surrounded by a thin layer of soma cells that later forms the wall of the daughter sporocyst (Cort and Olivier, 1943a, Figs. 9 and 10; Cort, Ameel, and Olivier, 1944, Figs. 10–12; Cort and Olivier, 1943b, Fig. 3).

While the evidence is far from complete, so many of the recent observations on the germ cell cycle of the digenetic trematodes fit in with the germinal lineage hypothesis that I have come to accept it and to base my thinking on trematode life cycles on it. However, much still needs to be done. Further studies similar to those of Chen and Rees are needed on other groups, especially those in which the secondary germinal sacs are daughter sporocysts. Especially significant would be further cytological studies on the chromosome number in the germinal cells throughout the germ cell cycle of species belonging to different groups. Further investigations should also be made of the germ cell cycles of the groups with branched mother sporocysts, the Bucephalidae and the Brachylaimidae, to check the work of Woodhead (1931, 1932).

MECHANISMS FOR THE MULTIPLICATION OF INDIVIDUALS IN THE GERMINAL SACS

Whatever its evolutionary origin, it is evident that the reproduction in the germinal sacs in the intermediate hosts of the digenetic trematodes greatly increases the number of individuals that can develop from a single fertilized ovum. The evidence presented above, especially from the studies in which the cells of the germinal line were followed in the germinal sacs (Chen, 1937; Rees, 1940), indicates a multiplication by the direct division of the germinal cells in the sporocysts or rediae, which is interpreted as a polyembryony of the fertilized ovum extending throughout the series of germinal sacs. This reproduction of the cells of the germinal line by direct division may be in some cases produce only a rather limited number of individuals. For example, in *Parorchis acanthus*, Rees (1940) found no multiplication in the first generation, since only one germinal cell is set aside in the development of the miracidium, which develops precociously into a single first generation redia in the body cavity of the miracidium. About 20 or more second generation rediae are produced from the germinal cells of this first generation redia. In each of these, the cells of the germinal line produce a number of cercaria embryos. Rees makes no definite statement of the number of cercarial embryos in each daughter redia, but shows about 30 in her drawing of an optical section (l.c., Fig. 31). It appears, therefore, that in this species the multiplication of cells of the germinal line in the germinal sacs produces about 1000 cercariae from a single fertilized ovum. There are other cases in which this multiplication is even more restricted. In the amphistome species, *Cotylophoron cotylophorum*, Bennett (1936, p. 62) estimated that with only one generation of rediae the total cercarial production from a single fertilized ovum was about 225. He quoted the work of Takahashi, who found that each mother sporocyst of another amphistome, *Paramphistomum cervi*, produces on the average nine rediae, each of which gives rise to about 20 cercariae, making the total cercarial production under 200. The most restricted multiplication in the intermediate host in any of the groups of digenetic trematodes for which the life cycle is known appears to occur in the family Cyclocoeliidae. Here a single redia develops precociously in the miracidium, and this redia produces cercariae directly. Stunkard (1934) in his study of the life cycle of a species in this family, *Typhlocoelum cymbium*, noted that one redia eight weeks after infection contained 22 cercariae in different stages of development and a group of germinal cells near the posterior end. Another redia the same age had 16 cercariae and some additional germinal material. It seems reasonable to estimate that in this species the total number of cercariae produced by a single fertilized ovum is well under 50.

Whenever the mother sporocyst produces a number of first generation rediae, and a second generation of rediae is present, the number of cercariae will be greatly increased. While the counts given by Ameel (1934) for *Paragonimus kellicotti* were rather variable, they indicate that between 10,000 and 20,000 cercariae may be produced from a single fertilized ovum. In species with two generations of large rediae, like certain of the Echinostomidae or Fasciolidae, the numbers are probably well over 25,000.

In the two cases listed above in which the cells of the germinal line were followed through the germinal sacs, multiplication appeared to be only by direct division of germinal cells. In these two species which belong to two quite unrelated families the secondary germinal sacs were rediae.

It can possibly be suggested, therefore, that in groups with rediae as secondary germinal sacs in which rather limited numbers of cercariae are produced, the multiplication of individuals may be entirely by direct division of the cells of the germinal line. The numbers will, of course, as suggested above, be greatly increased when there are two generations of rediae present.

Evidence that another mechanism for increasing the number of individuals, besides direct division of the germinal cells, is involved in the reproductive processes in the germinal sacs of the digenetic trematodes was first given by the investigations of Brooks (1930). This author found loose masses of germinal material, which he called "germ-masses," in the secondary germinal sacs of the species he studied. To these structures he assigned a very important role in reproduction. He found germinal cells, which he called "antecedent germ cells," lying in the body cavities of very immature daughter sporocysts and rediae. According to his interpretation, loosely organized "germ-masses" are produced by the division of these cells, the unicellular components of which later separate and develop into cercarial embryos. This process he interpreted as a polyembryony. He considered that the polyembryony of germ-masses is the fundamental mechanism for the multiplication of individuals in the germinal sacs of the digenetic trematodes, and either described these structures or at least mentioned them as present in all the sporocysts and rediae that he studied. In the three recent studies of the germ cell cycle of the digenetic trematodes mentioned above (Cable, 1934; Chen, 1937; Rees, 1940) the authors have noted specifically that no germ-masses like those described by Brooks are present in the rediae, and indicated that multiplication is entirely by direct division of the cells of the germinal line. Cort and Olivier (1941), however, found germ-masses in the daughter sporocysts of the strigeids like those that Brooks (1930, Pt. III, Figs. 40 and 42) described and figured for members of this group. They also found them in the mother sporocysts of several species of this group. Later, germ-masses were found in the sporocysts of schistosomes and plagiorchiids (Cort and Olivier, 1943a, b; Cort, Ameel, and Olivier, 1944; Cort and Ameel, 1944). The interpretation given in these studies of the method of reproduction of the germ-masses is somewhat different from that of Brooks.

The germ-masses, as described by the author and his co-workers, are irregular structures composed of both unicellular and multicellular components. Reproduction by germ-masses is considered as a special type of polyembryony, in which the largest multicellular components continually split off from the masses. These multicellular components are really early stages of embryos which have started their development in the germ-masses. In certain cases, as in the daughter sporocysts of the strigeids and plagiorchiids, the germ-masses persist for a long time and produce large numbers of embryos. Thus they may play a major role in reproduction and in these two groups are chiefly responsible for the enormous numbers of cercariae produced. The direct division of the cells of the germinal line, i.e., the primary polyembryony of the zygote (fertilized ovum), also plays a part in reproduction in these groups. It appears, therefore, that germ-masses are produced only in certain of the groups of the digenetic trematodes and are a special mechanism for greatly increasing the production of individuals. In order to make clear these interpretations, a brief discussion will be given of the recent work of the author and his co-workers on the germ cell cycles of the strigeids, schistosomes, and plagiorchiids.

Germ cell cycle in the strigeids (Cort and Olivier, 1941). The miracidium of the strigeids develops from the fertilized ovum in the egg outside of the definitive host. In the few miracidia in this group that have been carefully studied, only a few germinal cells were found. No information of significance is available on the early stages of the development of the mother sporocysts. Later stages are known for several different species. They are elongate inflated sacs which contain various stages of daughter sporocyst embryos and a few germ-masses (6 to 12). These mother sporocyst germ-masses are rather irregular structures composed of variable numbers of components, both unicellular and multicellular (l.c., Figs. 3–8). The largest multicellular components are at the ends of the germ-masses and are sometimes observed to be partly split off. They have exactly the same structure as the smallest daughter sporocyst embryos that are free in the mother sporocysts. In slightly older daughter sporocyst embryos that have reached a length of about 0.07 to 0.08 mm., the wall is clearly separated from the contents of the body cavity (l.c., Fig. 11). The germinal materials that they contain at this stage consists of a number of small germ-masses.

In the later stages of the daughter sporocyst embryos, including forms up to about 1 mm. in length, which appear ready to escape from the mother, the body cavity contains only germ-masses, varying from about 12 to 24 in number (l.c., Figs. 12, 13, 14). These germ-masses (l.c., Figs. 15–17) are composed of both unicellular and multicellular components and resemble those found in the mother. No separate germinal cells were ever found in the body cavities of any of the daughter sporocysts examined. The germ-masses persist all through the life of the daughter sporocysts after they invade the tissues of the snail, and are found even in those that appear very old and partly degenerate. At about the time that the daughter sporocysts escape from the mother, very small cercarial embryos are found free in their body cavities among the germ-masses. The smallest of these have exactly the same structure as the largest end components of the germ-masses. In the later stages of the daughter sporocyst, even in the oldest, very immature cercarial embryos are always present along with the germ-masses.

The observations summarized above (Cort and Olivier, 1941) have made it possible to suggest the course of the germ cell cycle in the superfamily Strigeoidea. The evidence seems to indicate clearly that the embryos both of the daughter sporocysts and cercariae are formed by the breaking off of the largest multicellular components of germ-masses. This has been interpreted as a polyembryony. It is postulated that the germ-masses are formed from cells of the germinal line in the early stages of the development of the mother and daughter sporocysts, although this has not as yet been observed. In the mother sporocyst, the small numbers of germ-masses that are formed persist throughout the life of this stage and produce a series of daughter sporocyst embryos. The number is not very large (about 100 to 200), since they grow to considerable size and remain as parasites in the tissues of the intermediate host. Early in the development of each daughter sporocyst embryo, the cells of the germinal line, after a brief period of multiplication, produce the germ-masses which are such prominent structures in the body cavities of the developing daughters inside the mothers. These are more numerous than the germ-masses of the mother, but still the number in each daughter sporocyst is not very great in the strigeid species so far studied (12 to 24). They persist throughout the life of the daughter sporocysts in the snail's tissues and produce a constant stream of cercarial embryos, the total number of which in each daughter sporocyst probably reaches several thousand. In fact, in an immature daughter sporocyst in which no cercariae were even approaching maturity, over a thousand cercarial embryos were counted. It, therefore, seems not unreasonable to estimate that from several hundred thousand to over a million cercariae can be produced in the strigeids from a single fertilized ovum. This extraordinary multiplication of individuals in the germinal sacs is due for the most part to the reproductive activity of the germ-masses, especially in the daughter sporocysts, since only a limited amount of direct division of germinal cells would be needed to produce the small numbers of germ-masses in the mother and daughter sporocysts. The life cycle of the strigeids, therefore, is interpreted as an alternation of three generations, in which the multiplication of the cells of the germinal line (primary polyembryony) is limited to two very brief phases in the early development of the mother and daughter sporocysts, and reproduction of the germ-masses in both the mother and daughter sporocysts (secondary polyembryony) is chiefly responsible for the enormous numbers of cercariae that are produced.

Germ cell cycle in the schistosomes (Cort and Olivier, 1943a; Cort, Ameel, and Olivier, 1944). The larval stages of the schistosomes, or blood flukes, are so similar to those of the strigeids that the superfamily Schistosomatoidea is placed in the same suborder with the Strigeoidea. However, the two groups show considerable differences in the germ cell cycle in the germinal sacs. The body cavity of a schistosome miracidium contains numerous separate germinal cells (Price, 1931; Tang, 1938; Wall, 1941), indicating that during its development there has been a considerable multiplication of the cells of the germinal line. In very young schistosome mother sporocysts which were found in snails experimentally infected with the miracidia of *Schistosomatium douthitti* (Cort, 1915), the germinal cells are distributed throughout the body cavity and attached to the wall by strands (Cort, Ameel, and Olivier, 1944, Fig. 1). In slightly older mother sporocysts (l.c., Figs. 2 and 3) these germinal cells have increased in number, and in still later stages each develops directly into a daughter sporocyst embryo. More than 200 daughter sporocysts may be produced by a single mother. The daughter

sporocyst embryos, while still in the round "germ ball" stage, consist of a group of germinal cells enclosed in a thin membrane (l.c., Fig. 10). These cells of the germinal line continue to multiply by direct division throughout the development of the daughter sporocyst embryos inside the mother, until about 200 are present in a daughter that is ready to escape (l.c., Fig. 15). After the daughter sporocysts of this species have established themselves in the tissues of the intermediate host, they grow into large elongate thin-walled sacs. In them most of the germinal cells appear to develop directly into cercarial embryos. In some of these sporocysts, however, after all the germinal cells have started development, a few very simple germ-masses are present (l.c., Figs. 21–24). It is suggested that these germ-masses break up to form cercarial embryos by secondary polyembryony, since in older daughter sporocysts only developing cercariae are found. Multiplication of individuals in the germinal sacs of *S. douthitti*, therefore, appears to be due very largely to the direct division of the germinal cells (primary polyembryony), and only to a very slight extent to the secondary polyembryony which seems to occur only in the daughter sporocysts. This results in a scale of cercarial production which is much less than in the strigeids. The primary polyembryony in this species is more effective in the reproduction than in any other group that has been studied, since it is evident that at least 40,000 cercariae can be produced from a single fertilized ovum by this process alone.

In the study of the germ cell cycle of another schistosome, *Cercaria stagnicolae* Talbot, 1936, germ-masses were found to play a more important role in reproduction than in *S. douthitti* (Cort, Ameel, and Olivier, 1944). In this species, germ-masses are present in both the mother and daughter sporocysts. They are of the same simple type as those found in the daughter sporocysts of *S. douthitti*, but have larger numbers of unicellular components (l.c., Figs. 8, 8a, 21). No very young mother sporocysts of *C. stagnicolae* were available for study, but the presence of a number of germ-masses in the later stages suggested that multiplication by direct division of the germinal cells must be much less than in the mother sporocysts of *S. douthitti*, since about the same number of daughter sporocysts are produced in both forms. On the other hand, in this species the germ cell cycle in the daughter sporocysts, while they are still within the mother, is almost exactly like that of *S. douthitti*, since at the stage when they are ready to escape they contain only numerous separate germinal cells (l.c., Figs. 9, 10, 11). However, in older daughter sporocysts from the tissues of the snail such large numbers of germ-masses are present that these structures certainly must be an important factor in reproduction (l.c., Figs. 16–20). This combination of a primary polyembryony in the daughter sporocyst embryos, which produces a number of separate germinal cells (about 200), with what appears to be a considerable phase of secondary polyembryony results in a cercarial production in *C. stagnicolae* that is much greater than in *S. douthitti*.

As compared with the strigeids, therefore, the primary polyembryony of the cells of the germinal line plays a much more important role in reproduction in the germinal sacs in these two schistosomes. Also, the germ-masses are simpler structures than those of the strigeids, and their multiplication by secondary polyembryony appears much less important and more transitory.

Germ cell cycle in the plagiorchiids (Cort and Olivier, 1943; Cort and Ameel, 1944). The miracidia in the plagiorchiids are usually very small and appear to contain only a few germ cells (Talbot, 1933; Walker, 1939). They usually complete their development in the eggs while still in the uterus of the adult worms. In the few cases in which very young mother sporocysts have been studied, they appear to contain only separate germ cells. The youngest mother sporocysts encountered in our studies (Cort, and Ameel, 1944, Figs. 1 and 4) already contained large numbers of separate germ cells. No germ-masses have ever been seen in plagiorchiid mother sporocysts, so it appears that during this stage multiplication is entirely by direct division of the cells of the germinal line. In different species from 500 to several thousand daughter sporocysts are produced from one mother.

In the species of plagiorchiids we studied, the very immature daughter sporocyst embryos, like those of the schistosomes, consist of a thin outer membrane surrounding a number of separate germinal cells. Very soon, however, these cells begin to develop into cercarial embryos, and in later stages the developing daughter sporocysts within the mother contain no separate germ cells, but only cercarial embryos and a single large complicated germ-mass (Cort and Olivier, 1943b, Figs. 3, 4, 6, 8, 11; Cort and Ameel, 1944, Figs. 5, 9, 10). It appears, therefore, that in the early

stages of development of the daughter sporocysts there is only a brief phase of multiplication of the cells of the germinal line, and that one of them develops into a germ-mass while the others produce cercarial embryos directly. The germ-masses in the daughter sporocysts of different species vary in structure (Cort and Olivier, 1943, Fig. 13; Cort and Ameel, 1944, Figs. 7, 8, 10). In general they are considerably larger than those of either the schistosomes or strigeids, and have more components, both unicellular and multicellular. Each daughter sporocyst contains only one germ-mass, which persists throughout its whole life. In fact, in the very oldest plagiorchiid daughter sporocyst we ever examined, the germ-masses had the same appearance as in the younger stages and were still producing cercarial embryos. As in the other groups, we interpret the reproduction of the germ-masses in the daughter sporocysts of these plagiorchiid species as a special type of polyembryony in which the largest multicellular components are constantly being split off.

It can be seen from the above discussion that the germ cell cycle in those plagiorchiids we had the opportunity to study differs fundamentally from that in the strigeids and schistosomes. In the primary germinal sacs, germ-masses appear to be entirely absent, and there is a much greater multiplication of the cells of the germinal line by direct division (primary polyembryony) than has been found in mother sporocysts in any other group. On the other hand, the primary polyembryony in the early stages of development of the secondary germinal sacs produces only a few cercarial embryos and a single germ-mass in each daughter sporocyst. The secondary polyembryony of these germ-masses lasts throughout the whole life of the secondary germinal sacs and is chiefly responsible for the enormous cercarial production that is characteristic of this group.

CONCLUSIONS AND SUMMARY

Although the stages of the digenetic trematodes in the molluscan intermediate host have been studied by numerous investigators since they were first discovered early in the 19th century, it has only been in the last few years that a real understanding has begun to develop of the processes involved in their reproduction. Most of the recent work on the germ cell cycle in this group has supported the germinal lineage hypothesis. According to this view, reproduction in the germinal sacs (sporocysts and rediae) is a multiplication of the cells of the germinal line. This process starts with the fertilized ovum inside the egg and terminates with the production of mature ova and spermatozoa in the ovaries and testes of the adult. In this multiplication of the cells of the germinal line both somatic and germinal cells are produced. The somatic cells first form the primary germinal sac (the miracidium-mother sporocyst stage), and in most groups the secondary germinal sacs, either a single generation of daughter sporocysts or one or two generations of rediae. Finally cercariae are produced, which after entrance into the definitive host develop into the adults.

According to the germinal lineage hypothesis, the multiplication of the cells of the germinal line is a polyembryony by which large numbers of germinal cells are produced from the original zygote (fertilized ovum). These cells remain separate from the soma of the germinal sacs and come to lie in their body cavities. Finally they form the ovaries and testes of the adults, and the polyembryony is followed by gametogenesis with the production of true germ cells, mature ova and spermatozoa, which have the reduced number of chromosomes. In fact, the germinal lineage hypothesis implies that these are the only cells in the whole life cycle of the digenetic trematodes that have the reduced number of chromosomes.

In the two species in which the germ cell cycle has been followed most completely, *Paragonimus kellicotti* and *Parochis acanthus*, the secondary germinal sacs are rediae. In these stages reproduction appears to be entirely by multiplication of the cells of the germinal line by direct division (primary polyembryony). In these forms the multiplication of individuals is much more limited than in certain groups like the strigeids, schistosomes, and plagiorchiids, in which the secondary germinal sacs are daughter sporocysts. In these latter groups the primary polyembryony is supplemented by a secondary polyembryony. Peculiar structures, germ-masses, which are composed both of unicellular and multicellular components, are present in the germinal sacs. From these there break off the largest multicellular components, which then develop into daughter sporocysts or cercarial embryos, as the case may be. In some cases this secondary polyembryony of the germ-masses may continue over considerable periods of time, producing large numbers of individuals.

In the germ cell cycle of the strigeids, super-

family Strigeoidea, secondary polyembryony of germ-masses has become the chief method of reproduction both in the primary and secondary germinal sacs. In the mother sporocyst a small number of germ-masses is present, which produce daughter sporocyst embryos throughout the whole life of the mother. In the daughter sporocyst embryos a slightly larger number of germ-masses is produced, which persist throughout the whole life of the daughters and give rise to very large numbers of cercarial embryos.

In the schistosomes or blood flukes, superfamily Schistosomatoidia, primary polyembryony of the germinal cells, both in the mother and daughter sporocysts, has a much larger part in the multiplication of individuals than in the strigeids. Secondary polyembryony, however, does occur, although the germ-masses are much simpler in structure and more transitory than in the strigeids.

In the plagiorchiids, superfamily Plagiorchioidea, the germ cell cycle is still different. The primary germinal sacs, the mother sporocysts, are complicated structures which produce larger numbers of daughter sporocysts than in any of the other groups in which the germ cell cycle has been studied. This multiplication appears to be entirely by direct division of the cells of the germinal line, primary polyembryony, since no germ-masses have been found. In the secondary germinal sacs (daughter sporocysts), however, primary polyembryony appears to be very limited. In each daughter sporocyst a single large germ-mass is produced at a very early stage which persists throughout its whole life and gives rise to very large numbers of cercarial embryos. Therefore, secondary polyembryony of germ-masses is largely responsible for the enormous numbers of cercariae produced by the secondary germinal sacs in this group.

As the germ cell cycles are studied in other groups of digenetic trematodes still different relations between primary and secondary polyembryony may be found; or perhaps even entirely different mechanisms for the increase in the numbers of individuals may be discovered. At present, the evidence seems to suggest that direct division of the cells of the germinal line (primary polyembryony) is the primary method of reproduction, and that polyembryony by germ-mass formation is a secondary adaptation that makes possible the extraordinary multiplication of individuals found in certain groups.

Finally, much further work is needed before the hypothesis of germinal lineage to explain the germ cell cycle of the digenetic trematodes can be considered as firmly established. At present it is the only view that seems to fit the great numbers of new facts that have been accumulated in the last few years on the embryology of this group. As a working hypothesis it appears to be a real aid in bringing order out of the confusion that has existed so long in the interpretation of the fundamental embryology of this very interesting group of organisms.

LIST OF LITERATURE

AMEEL, D. J. 1934. *Paragonimus*, its life history and distribution in North America and its taxonomy (Trematoda: Troglotrematidae). *Amer. J. Hyg.*, 19: 279–317.

BENNETT, H. J. 1936. The life history of *Cotylophoron cotylophorum*, a trematode from ruminants. *Illinois Biol. Monogr.* 14: 1–119.

BROOKS, F. G. 1930. Studies on the germ cell cycle of trematodes. *Amer. J. Hyg.*, 12: 299–340.

CABLE, R. M. 1931. Studies on the germ-cell cycle of *Cryptocotyle lingua* Creplin. I. Gametogenesis in the adult. *Quart. J. micr. sci.*, 74: 563–589.

——. 1934. Studies on the germ-cell cycle of *Cryptocotyle lingua*. Germinal development in the larval stages. *Quart. J. micr. Sc.*, 76: 573–614.

CHEN, PIN-DJI. 1937. The germ cell cycle in the trematode, *Paragonimus kellicotti* Ward. *Trans. Amer. Micr. Soc.*, 56: 208–236.

CORT, W. W., and LOUIS OLIVIER. 1941. Early developmental stages of strigeid trematodes in the first intermediate host. *J. Parasitol.*, 27: 493–504.

——, and ——. 1943. The development of the sporocysts of a schistosome, *Cercaria stagnicolae* Talbot, 1936. *J. Parasitol.*, 29: 164–176.

——, and ——. 1943b. The development of the larval stages of *Plagiorchis muris* Tanabe, 1922, in the first intermediate host. *J. Parasitol.*, 29: 81–99.

——, and D. J. AMEEL. 1944. Further studies on the development of the sporocyst stages of plagiorchiids. *J. Parasitol.*, 30 (In Press).

——, ——, and LOUIS OLIVIER. 1944. An experimental study of the development of *Schistosomatium douthitti* (Cort, 1914) in its intermediate host. *J. Parasitol.*, 30 (In Press).

DOLLFUS, ROBERT. 1919. Continuité de la lignée des cellules germinales chez les Trematodes Digenea. *C. R. Acad. Sci. Paris*, 168: 124–127.

ISHII, YOSHIO. 1934. Studies on the development of *Fasciolopsis buski*. Part I. Development of the eggs outside the host. *J. Med. Ass. Formosa*, 33: 1–30. (Japanese with English abstract).

PRICE, HELEN F. 1931. Life history of *Schistosomatium douthitti* (Cort). *Amer. J. Hyg.*, 13: 685–727.

REES, GWENDOLEN. 1939. Studies on the germ cell cycle of the digenetic trematode *Parorchis acanthus* Nicoll. Part I. Anatomy of the genitalia and gametogenesis in the adult. *Parasitology*, 31: 417–433.

——. 1940. Studies on the germ cell cycle of the digenetic trematode *Parorchis acanthus* Nicoll. Part II. Structure of the miracidium and germinal development in the larval stages. *Parasitology*, 32: 372–391.

STUNKARD, H. W. 1934. The life history of *Typhlocoelum cymbium* (Diesing, 1850) Kossack, 1911 (Trematoda, Cyclocoelidae). A contribution to the phylogeny of the monostomes. *Bull. Soc. Zool. France*, 59: 447–466.

TALBOT, S. B. 1933. Life history studies on trematodes of the subfamily Reniferinae. *Parasitology*, 25: 518–545.

TANG, C. D. 1938. Some remarks on the morphology of the miracidium and cercaria of *Schistosoma japonicum*. *Chinese Med. J., Suppl.* 2: 423–432.

WALKER, J. H. 1939. Experimental studies on trematodes belonging to the subfamily Reniferidae. *Trans. Amer. Micr. Soc.*, 58: 404–430.

WALL, L. D. 1941. *Spirorchis parvus* (Stunkard), its life history and the development of its excretory system (Trematoda: Spirorchiidae). *Trans. Amer. Micr. Soc.*, 60: 221–260.

WOODHEAD, A. E. 1931. The germ cell cycle in the trematode family Bucephalidae. *Trans. Amer. Micr. Soc.*, 50: 169–188.

——. 1932. The germ cell cycle in trematodes. *J. Parasitol.*, 19: 164.

MOSAIC EFFECTS IN DOMESTIC BIRDS

By W. F. HOLLANDER

INTRODUCTION

IN THE mythology of some ancient peoples, notably the Greeks, one reads of composite creatures such as centaurs, the griffin, the chimaera, the sphinx, and the nature god, Pan. Since they were supernatural the biologist is not interested in their anatomical and physiological arrangements. But composite or "mosaic" creatures do exist, on a less fantastic plane. Some are the result of the grafter's art, or other human manipulation. Still more interesting, however, are spontaneous mosaic conditions; they are rare, but a diligent observer can find an astonishing array of such oddities over a span of a few years. Many have been described or illustrated in scientific journals, breeders' magazines, and newspapers.

Like other kinds of variation, mosaicism is almost entirely found in domesticated species. It would seem absurd or astonishing to find a crow, for example, with buff, white, and black plumage, or a crest on its head, or feathers growing on its feet. Yet an ornithologist who would devote hours of study to such a crow would probably dismiss similar variations which can be found in almost any flock of domestic pigeons as "effects of domestication." So plentiful is variation in the barnyard that only the most bizarre attracts special attention. Likewise with mosaicism: common sorts such as the tortoise-shell cat, the calico goldfish, and the variegated flower receive a passing glance, while a gynandromorph honeybee or a half-green and half-blue parakeet or a bud sport on a fruit tree is a cynosure.

Ordinary variation, including both individual and varietal differences, has yielded to genetic analysis by relatively simple Mendelian methods during the years since 1900. Mosaicism, variation within the individual, has been a harder nut to crack. Its erratic occurrence baffled many students, and seemed to preclude the existence of any law. Prolonged and careful studies of mosaic phenomena in laboratory animals and plants have, however, produced some illuminating results. Birds have contributed to some extent in such investigations, but are less favorable than lower forms because of slow breeding and difficult cytology. The one great advantage possessed by birds is the capacity to grow many successive feathers from a given follicle.

Our understanding of mosaicism in birds is far from complete, and, such as it is, has trailed in the wake of progress made with lower forms. As will appear below, the problems encountered are often very complex and sometimes unique. It is the purpose of this review to bring together what bird material exists, to point out explanations, relationships, and differences, and to suggest possibilities for future study. Since no survey of mosaicism in general has appeared, I include a number of key references to work on other forms.

The subject of spontaneous mosaicism may be best introduced by a consideration of artificially produced mosaicism. The latter kinds sketch the possibilities and reveal important principles of development and regulation of growth. Two entirely different means of producing mosaicism are available: the old method of grafting, with some modern refinements; and the new and less precise method of irradiation with high-frequency radiation, such as x-rays.

Grafts may be made from one part to another of the same individual, or from one individual to another. In the former case there appears to be little difficulty, and the analogy may be made of a gardener transplanting shrubbery. Integumental structures such as large pieces of skin, the comb and the spurs (of the fowl), and feather primordia or portions of them have grown in various new locations; except for failure of innervation and the occurrence of some distortion, they maintain their characteristic features and do not de-differentiate (Danforth, 1928; Kozelka, 1929; Lillie and Wang, 1941, 1943).

In grafts from one individual to another more difficulties arise, but there are more opportunities

for increasing knowledge. At least with integumental grafts, antagonisms often develop, leading to death of the grafted tissue, soon after the operation or perhaps after several weeks. Many show little or no antagonism, however, even when the donor and host are of widely different types. In general the grafted tissue retains the donor characteristics and is not seriously altered by the host, except in the case of certain sex-limited characters, whose appearance depends on the hormone supply of the host. But such influence is limited; Kozelka (1929) notes that a male spur primordium grafted on a female host develops as in a male, and a female comb grafted on a male may not take on masculine character. With breed differences such as plumage characters—"silky," "henny-feathering," various colorations, and contrasting growth rates—the hosts showed no influence on the graft, and vice versa, in the experiments of Danforth and Foster (1929). Landauer and Aberle (1935) came to the same conclusion in reciprocal transplants between "frizzle" and normal fowls.

Danforth and Foster (1929), and Danforth (1935, 1937, and 1939) noted that in skin grafts differing in plumage color from that of the host, feathers along the graft line are occasionally themselves mosaic in coloration. The explanation of this phenomenon as the result of the migration of melanophore cells came later in studies of the behavior of these cells in embryo transplants.

Grafting in early embryos affords wider possibilities than are possible with older stages; antagonisms appear to be absent, and whole organs such as the eye or a limb bud can be accommodated by the host (Hamburger, 1941; Gayer and Hamburger, 1943). Chicks have even been hatched with the leg of a duck growing from the side, after early embryonic transplantation (Eastlick, 1941). With some characters it is clear that the graft is not influenced by the host, but frequently the host appears to regulate the growth of the graft; or mixture of host and graft tissue may occur to some extent so that interpretations are difficult. Melanophores and their precursors in particular have great powers of migration (Watterson, 1942; Foulks, 1943; Rawles, 1944). When melanophores of the host and graft differ strikingly, one can easily see that they govern pigmentation quite separately (Willier *et al.*, 1937–1941; Rawles, 1939; Dorris, 1939; Eastlick, 1939; Hamilton, 1940; Ris, 1941).

The ability of x-rays and other types of high-frequency irradiation to produce mosaicism has been recognized for only about 15 years. The radiation induces various genetic alterations in cell nuclei, such as mutations, loss of parts of or whole chromosomes, and rearrangements of chromosome structure. Since these changes are apparently random, and hardly any two nuclei will be affected identically, growth from irradiated tissue is usually mosaic. The most striking results follow treatment of embryos in early cleavage stages, or even of spermatozoa. With the use of "marker" genes the changes induced by the treatment may often be identified. This method offers unique possibilities in the study of embryology and morphogenesis. The work of Patterson (1929) and of Muller (1930) with the fruit fly, *Drosophila*, is of special interest in this line. The only related study in birds appears to be that of Munro (1938), who irradiated three-day-old chicks with a dosage of 1100–1400 r units, on only one side of the body. The result was lopsided growth, the treated side being somewhat stunted. This approach is too crude for genetic interpretations, especially since no "markers" were employed.

Artificial mosaics often so closely mimic spontaneous types that one is easily persuaded their origins are very similar. Thus, in place of the grafter's manipulations, it is conceivable that two zygotes might develop in one egg, and fuse. And instead of an x-ray treatment, cosmic radiation might disrupt the chromosomes. But there may be other possibilities.

Whatever the precise inciting agent, mosaicism usually consists of a genetic diversity of tissues. By study of the character of the diversity, it is sometimes possible to reconstruct the events in its production, or to eliminate one or more possible events from the explanation. A thorough knowledge of the ordinary variation, heredity, and embryology of the species is of fundamental assistance in such analysis of mosaicism.

The present survey is organized rather arbitrarily into four groupings: (1) sectorial mosaics, showing conspicuous asymmetry or patchwork of characters; (2) sex mosaics, or gynandromorphs; (3) variegation, showing a sprinkled or freckled effect; and (4) dubious conditions, such as piebaldness. As is evident from the existence of the last group, true mosaicism cannot always be distinguished from pathological or purely physiological differentiations between parts. The attitude I adopt is to consider these borderline cases possibly mosaicism until the evidence is more decisive.

SECTORIAL EFFECTS

The most striking kind of sectorial mosaic is the "half-and-half" effect. Usually the median line of the body is the boundary separating the different characteristics, though some cases show a more zigzag division, or even anterior-posterior separation. The origin of such types is thought to be some event producing diversity at the first cleavage division of the fertilized egg: a genetic change may distinguish one of the two blastomeres, or polyspermy may occur. An example of genetic change is afforded by the "claret" stock of *Drosophila simulans* (fruit fly); eggs from the females of this stock very often develop as mosaics of various sorts, and Sturtevant (1929) showed the cause to be non-disjunction (unequal distribution) of chromosomes. Polyspermy has been demonstrated to occur in several cases of mosaicism, again in insects. Apparently certain females have a tendency to produce binucleate eggs, and both nuclei attract sperms (Whiting, 1928; Goldschmidt and Katsuki, 1931; Crew and Lamy, 1939). Development of a haploid half of an embryo from a supernumerary sperm is also possible.

Other sectorial mosaics, showing one or more small areas of "unusual" character, are attributed to genetic alteration in such areas. Generally the origin of the change is thought to be relatively late in the development of the embryo, though certain characters which can be expressed only in particular organs furnish unsatisfactory evidence as to the time of origin. For example, if the feet differ in a claw characteristic known to be hereditary as a rule, one could not limit the possible mosaicism to the foot only—the origin might have been even at the first cleavage. Several kinds of genetic change have been found or indicated in cases of patchy mosaics. Wright and Eaton (1926) thought simple mutation the best explanation of a mosaic guinea pig; Sturtevant (1929), as noted above, found chromosome non-disjunction responsible for mosaicism in offspring of certain females of *Drosophila simulans*. Some sort of somatic segregation of traits initially heterozygous has been the explanation favored in certain cases of mosaicism in rodents (Pickard, 1929; Feldman, 1935). Jones (1937) has advocated somatic segregation of some sort to account for a number of types of mosaicism in plants. But proof of an explanation is difficult to obtain in most typical cases of patchy mosaicism because of the rarity of repetition. When recurrence is at all frequent, the condition may be better treated as variegation (q. v.).

In birds, clear-cut sectorial mosaics have been reported for the chicken, the pigeon, the turkey, the budgerigar (parakeet), and the canary. The cases for each species will be taken up in turn.

The first example reported in the chicken appears to be that of Crew (1928). He describes it as having "unusual crazy-quilt distribution of red pigment in its white plumage and with the right leg, yellow in color, so much shorter than its fellow, the color of which was white, that the bird not only looked lop-sided but was forced to adopt a most peculiar gait." It was a cock, from the mating of a Light Sussex hen (white-skinned) with a Rhode Island Red male (yellow-skinned). This cross was popular in England; the F_1 chickens had white skin, as a rule, and the males had whitish plumage (due to the dominant sex-linked "silver" gene). Three unexpected features occurred therefore in the mosaic: red in the plumage, yellow on a leg, and size asymmetry. Breeding tests failed because the bird did not fertilize any eggs. At autopsy the testes appeared normal; all the bones of the right side except for the head were found to be smaller than those of the left. Crew suggested loss or non-disjunction (unequal distribution) of an entire chromosome, bearing the genes for white skin and white plumage, from the right side of the early embryo. Size asymmetry would be a natural consequence of abnormal chromosome proportions. However, the true explanation may be elsewhere; skin color is not sex-linked, while plumage color is, so that more than one chromosome seems involved in the mosaicism.

Lambert (1929) described a female, probably of the Leghorn breed, which also showed yellow skin on the right side and white on the left, but without evident size asymmetry. He proposes non-disjunction as the basis. Hutt (1929) suggests that since there was no size asymmetry, a less drastic cause, such as simple mutation, was involved.

Knox (1931) briefly mentions another case like Lambert's, and also a fowl with white legs, one streaked with yellow. Both were F_1 from a cross of Black Langshan × White Plymouth Rock. Knox devotes more attention to a hen having one shank yellow, the other green (yellow plus dark melanic pigment). This bird was also an F_1 hybrid, from White Wyandotte hen × Rhode

Island Red cock. The Wyandotte breed may occasionally have green shanks, but is ordinarily yellow-shanked. Knox favors simple mutation to green as the cause of this mosaic.

Crew (1932) and Crew and Munro (1938, 1939) have described about ten additional cases of skin-color mosaicism, most being from crosses of Rhode Island Red × Light Sussex. Some were not half-and-half, but patchy; the yellow side might be the left as well as the right; and the sex could be either male or female. Two of the birds were gynandromorphic, however, and will be treated more in detail in that connection. Body size asymmetry was observed in the "half-siders," but was either very pronounced (10–15 per cent difference in bone lengths) or slight (2–3 per cent difference). The yellow side was the smaller except in the gynandromorphs. Crew and Munro (1938) believe that two sorts of chromosome aberrations can explain all the findings, as follows: (a) Loss of the chromosome bearing the dominant white-skin gene, in a heterozygote, would leave the yellow-skin recessive gene in the other chromosome unopposed in determining skin color. Some (slight?) size asymmetry may be expected to result as well, the chromosome loss producing growth deficiencies. (b) Non-disjunction would be expected to result in a more exaggerated size asymmetry, and two possible skin-color effects: if the chromosome bearing the white-skin gene failed to enter one daughter cell in mitosis, this cell would possess only the yellow-skin gene, and the sister cell would possess two white-skin genes and a yellow. From such an origin would arise a bird with one side small and yellow-skinned, the other side large and white-skinned. On the other hand, if the chromosome bearing the yellow-skin gene failed to enter a daughter cell, this side of the bird would be small with white skin, and the other side, having two yellow genes and one white, would be large and (Crew and Munro assume) yellow-skinned. Furthermore, they believe that even the gynandromorphism can be fitted into this scheme: if the right side of a female embryo gains the additional chromosome, the gonad of this side (normally degenerate) will become testis-like.

The apparent frequency of these skin-color mosaics may be due in part to prevalence of breed crossing in recent years; chromosome aberrations in pure breeds would not be expected to attract much attention, since the effects on skin color would be slight. Crew and Munro (1939) note, however, that more than one case has occurred in one family, so that a familial tendency to aberration of this particular chromosome may be suspected.

Two of the remaining cases of fowl mosaics are biological puzzles of the highest order. The first was described by Roberts and Quisenberry (1935). The head and left side of the body were characteristic of the Light Brahma breed—large body size, feathers on the foot, and "columbian" (mainly white) plumage color; the right side of the body resembled the Plymouth Rock breed, with smaller size, no foot feathering, and "barred" plumage color. The bird's sex was not recorded. Its pedigree also was cloudy; its mother was a Plymouth Rock, but cocks of both breeds were in the flock. Roberts and Quisenberry discussed various possible explanations. Hybrid origin seems unavoidable, yet the parental characters failed to unite as usual, or else were exposed by loss of the dominant traits from each parent on one side—a highly improbable coincidence. The ordinary appearance of hybrids from these breeds would be mainly like the Brahma parent except in plumage color, which would be barred in males, black in females. Castle (1935) thought origin from a binucleate ovum, fertilized by both kinds of sperms, was the best explanation, but as Roberts and Quisenberry (1935b) pointed out, the Columbian plumage color should not appear on the hybrid side, since it is recessive. Munro (1938) suggests non-disjunction as an alternative; he assumes that the original zygote was hybrid, and that the genes for foot feathering and plumage color (columbian) are borne on a single chromosome. Then at the first or second cleavage division, if this chromosome failed to enter one cell, the mosaic condition would follow, including size asymmetry. However, the additional assumption is needed that the side gaining the extra chromosome could thereby show the columbian color, by overcoming the dominance of the other allele.

The second "impossible" composite was reported by Vecchi (1936). As indicated in fig. 1, the right side differed from the left in having feathered foot, naked neck, red ear-lobe, brownish-black plumage color with little white, normal male reproductive system, larger wattle, and larger skeleton. The left side had no feathers on the foot, but normally feathered neck, white ear-lobe, mottled plumage, smaller size, and partly feminized reproductive system—ovotestis, but

no oviduct. In general the features of the right side resemble the "Transylvanian Naked-neck" breed, while the left side is like the Leghorn. Since both of these breeds occurred where the mosaic appeared, Vecchi considered the bird a probable hybrid by origin. No progeny were reported. Crew and Munro (1938) reviewed this case, and again proposed non-disjunction of a single chromosome to explain the whole condition. In such a case it is necessary to assume linkage of foot feathering, naked-neck, ear-lobe color, and possibly other genes; origin from a binucleate egg and double fertilization seems a less risky explanation. But at the present time no explanation seems very probable; it is to be hoped that any similar specimens in the future will be more thoroughly studied and progeny-tested.

One other sectorial mosaic in the fowl was reported by Crew and Munro (1938). This was an Old-English Game Bantam hen, whose plumage was spangled (white-tipped) on the right side but not on the left. Mated with a spangled cock she produced both spangled and non-spangled young. Since the spangled character was shown to be recessive in other tests, the mosaic was considered heterozygous, at least on the left side (plumage and ovary). The mosaic condition may have originated by loss of the chromosome bearing the dominant allele, on the right side.

One mosaic turkey has been reported, by Asmundson (1937). It was a crossbred (F_2) female of Bourbon Red and Bronze origin. She showed both ancestral color conditions separately: wings and most of body plumage red; head, neck, and tail bronze. Ordinarily a cross of these colors gives a blended effect. The bird was mated with a Bourbon Red male, and produced only red offspring; the genetic constitution of the ovary seems to agree with that of the body plumage. Asmundson discussed several possible explanations,

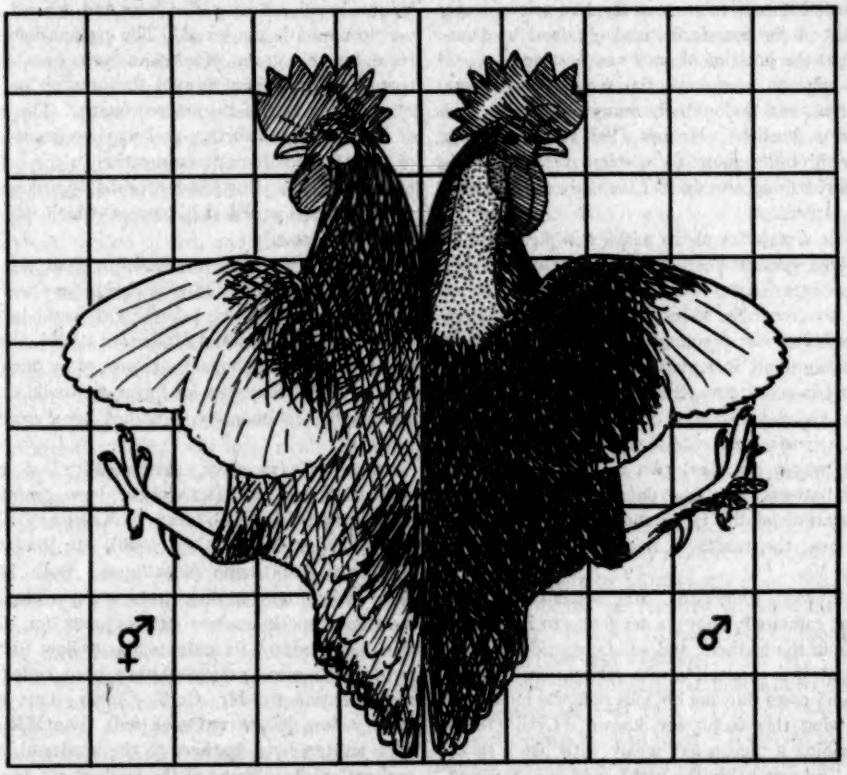

FIG. 1. A SKETCH SHOWING THE APPEARANCE OF VECCHI'S (1936) GYNANDROMORPH-MOSAIC

and considers non-disjunction in an early cleavage stage in a hybrid most probable. But no size asymmetry was observed. In my opinion the true explanation remains to be found, and it will probably be the same as the basis for the fowl mosaics of Roberts and Quisenberry, and of Vecchi. Before leaving this case it should be noted that at the junctions of the large differing regions of color, some feathers were themselves mosaic, varying in appearance from a patchwork to more intimate mixture of the two colors, reminiscent of the mosaic feathers obtained by Danforth at the junction of graft and host areas.

In pigeons many sectorial mosaics have been reported, and undoubtedly many more have "hid under a bushel." Holmes (1921) says that in Italy breeders refer to specimens colored differently on opposite sides of the body as "scherzo" (joke) pigeons.

Since a majority of the mosaics in pigeons have involved genetic characters, usually color types whose inheritance is well established, it seems best to group the cases according to the genes concerned. For present purposes a minimum of of background information about these genetic factors is given: first, the descriptive name of the gene; and next, whether it is dominant or recessive in crosses with wild-type, or normal standard type, whose plumage color is blue-gray with a black pattern. For more detailed descriptions and illustrations of the types and their genetic interrelations, the reader is referred to Levi (1941, chap. V).

"Ash-red" (dominant, and sex-linked). This factor commonly shows a tendency to have dark flecks in the feathers, and will be considered more intimately in connection with variegation. Nearly a dozen cases showing obvious sectorial mosaicism involving this factor are known. Lyell (1887), describing a pigeon as "mealy with black shoulders," was probably the first to put one on record, but he gave no data such as sex or pedigree. All the remaining cases known have been males heterozygous for the ash-red factor (by pedigree, progeny test or both). Most of them have been described and illustrated, by Levi and Hollander (1939), Hollander and Cole (1940), and Levi (1941, on color plate). Several have not been published, but have been examined by me; they were called to my attention by Mr. W. M. Levi, and Major C. E. Goodwyn, among whose birds the mosaics appeared. In all cases the arrangement of the differing areas has been irregular, even haphazard, like camouflage daubing. Nevertheless, these areas persist through repeated moults, with one exception noted by Levi and Hollander (1939), where a large part of a wild-type area was invaded by ash-red. In only one case did the wild-type area exceed the ash-red in size, and this bird was so largely white otherwise, that the true arrangement is unknown. The presence of white plumage (piebaldness) was noted in at least half of these mosaics; and most of the cases were in the Homer breed. Both piebaldness and ash-red are very common in the breed. The explanations offered for this group of mosaics have been very tentative, but center around the idea of loss or reverse mutation of the ash-red factor. The lack of females is noteworthy, and may be suggestive of some sort of somatic segregation in the origin of the mosaics. But there is probably a connection with the variegation process, which will be considered later.

"Brown" (recessive, sex-linked). One mosaic showing brown and wild-type regions, as well as white, or grizzling (see below), was found in the King breed by Levi and Hollander (1939). Subsequently this bird, a male, was proved by progeny test to be heterozygous for brown and wild type. For further comment on this bird, see *"grizzle,"* below.

"Dilution" (recessive, sex-linked). Two mosaics involving this factor have been reported, both in the red Carneau breed, by Keesling (1924), and by Hollander and Cole (1940). In the latter case there was some piebaldness. Both birds were males; no breeding tests were made, but Keesling's specimen was heterozygous for dilution, since one of its parents was yellow (dilute red). Two more examples have been called to my attention by Mr. C. F. Graefe. One is a male yellow (dilute recessive red) Giant Homer with scattered red feathers on the head and neck regions, chiefly. Some of the feathers are mosaic themselves. This bird's sire was heterozygous for dilution, and the dam was dilute. Progeny test has shown that the mosaic breeds as homozygous dilute. The final case is a female yellow mongrel Homer with a patch of red feathers on the back. In this case also the dam was dilute, the sire heterozygous. No breeding test is available for the mosaic. It seems difficult to make any conclusion as to the genetic origin of these cases, at present.

"Grizzle" (dominant). A female Homer-Carneau mixture, showing the grizzle trait except for

one wing, was reported by Levi and Hollander (1939). Breeding tests as well as her pedigree proved that she was heterozygous for grizzle. Some piebaldness was also present.

The male brown mosaic (above) also was found by progeny test to be heterozygous for grizzle (not published). Since his brown areas were phenotypically free of grizzle, the mosaicism appears to be compound. Piebaldness was also present, enough to confuse the issue, perhaps. It is not certain whether the grizzle factor involved here is typical, on that account. As will be brought out under variegation, there appear to be two different types known as grizzle, but genetically distinct, the typical form seemingly the more stable in the soma.

"Recessive red" (recessive). With this factor it seems advisable to divide the mosaics into two groups: one of preponderantly wild-type color with small regions of red, and the other having the reverse arrangement. In the first group about half a dozen cases are known. Metzelaar (1926) mentions a case; this was more carefully described in correspondence (Hollander and Cole, 1940). The red areas were chiefly limited to the primary wing feathers of each side, and to the neck. The bird was a female F_1 hybrid from Silver King × Red Carneau. There was apparently no piebaldness. Hollander and Cole (1940) described three males with red areas located mainly in the shoulder regions. Two were sibs and showed the grizzle character; the third, having the most extensive red areas, was piebald. No progeny tests were made, but these birds presumably were heterozygous for red, since the color was segregating in their families. Two additional cases of unknown sex and origin have been noted by Mr. R. W. Donady (information from correspondence, 1941, courtesy of Mrs. N. E. Mehringer). Both were specimens of the Flight breed, which is always piebald; one was described as "black with one solid red wing," and the other, "black and white mottled with a perfect deep yellow V on the back of the neck." As a working hypothesis one can assume loss or mutation of the wild-type allele in a heterozygote has occurred in this group; some sort of somatic segregation is equally probable, though.

In the second group of red mosaics, where the wild-type areas are small, it seems necessary to look for a different explanation. About a dozen cases are known. Four are mentioned by Horlacher (1930), and were more extensively treated by Hollander and Cole (1940), who also discuss three more cases. Frequently only one wild-type feather was seen on a specimen, so that they hardly seem to justify the name sectorial mosaic; but they seem best considered here with others having larger areas affected. None of these mosaics showed piebaldness; most were of the Tumbler breed. The parents of one (male) were both recessive red; for four of the others the dam was red and the sire heterozygous. Four of the mosaics were relatives, though not very close. A male and a female were progeny-tested and bred as red homozygotes. Two more mosaics of this kind, but in the Homer breed, have been bred by Mr. E. A. Klotz (personal communication); they are mother and son by a recessive red male. Each has one or two wild-type feathers, and there is no piebaldness. Mr. C. F. Graefe has bred three such mosaics. One is a male of the King breed, recessive red except for most of the tail region, which is wild-type. The sire was heterozygous, the dam homozygous for red. No progeny test information is available. The second mosaic is a male Giant Homer having a few wild-type feathers; both parents were red. The third case is a female Giant Homer having one wild-type feather; her sire was heterozygous, her dam homozygous for red. This mosaic is partly piebald. We may conclude for this group that reverse somatic mutation from recessive red to wild type is the most plausible explanation. There may be a slight familial tendency involved.

"Spread" pattern (dominant). The first mosaic of this factor was reported by Hollander and Cole (1940). It was a Homer, black on the right half of the body and wild-type on the left. Both parents were black, the sire (and perhaps the dam) heterozygous for wild type. This bird was discovered by Mr. W. Van Riper. It proved to be a female, and produced, with a wild-type male, at least eight young, all wild-type (data obtained by Dr. L. J. Cole). Her ovary thus appears to agree with the plumage of that (left) side of the body in not having the spread-pattern factor.

A female of the Florentine breed, piebald but otherwise very similar in character to the Homer just discussed, was reported with a photograph by Levi (1941, p. 232). No other data were secured for this specimen, unfortunately. An apparently similar "half-sider" was figured in Robert Ripley's "Believe it or not" feature in newspapers of Nov. 16, 1942, except that the

spread-black is shown on the right side; no information has been obtainable as to sex or breeding.

In the two "half-sider" females above, it was observed that the division line between the different color regions was roughly median, but not regular. A number of feathers near the boundary were themselves mosaic, usually showing longitudinal striping. When plucked, such mosaic feathers regenerated with almost identical patterns of striping (Hollander and Cole, 1940).

The above cases showed no evident asymmetry of body size. Perhaps they arose from binucleate eggs; at any rate, non-disjunction seems a very unlikely explanation here. On the other hand, non-disjunction or some other chromosome aberration may explain another case described by Hollander and Cole (1940). This specimen was asymmetrical, the side with wild-type color (right) having much shorter bones, and the feathers showing defective structure on this side; numerous feathers were mosaic, with longitudinal striping. The bird was not a typical half-sider, however, since only the ventral regions showed a median line of division, and there was much irregularity. The sex was female; no progeny test was made. Its dam was heterozygous for spread black, and was piebald, while the sire lacked these factors. Piebaldness was present in the mosaic, and quite asymmetrical.

The only other spread-pattern mosaic known to me is a male Carneau-Homer mixture, wild type except for several black and striped feathers on the shoulder and breast of the right side. Its parents were both heterozygous for the spread pattern. A progeny test of this bird gave over twenty young, none showing any sign of the factor (data furnished by Mr. W. M. Levi). A possible explanation of the mosaicism may be that supernumerary sperms survived to contribute some tissue to the embryo. No other basis seems very plausible.

"*Checker*" pattern (dominant). A female of the Starling breed, given to the author by Dr. J. D. Reynolds, showed the checker pattern on the left wing, while the right wing showed the recessive barred pattern. None of her nine offspring showed the checker pattern, so that the ovary seems to have been genetically different from the wing of that side. Nothing is known of the parents of the mosaic, unfortunately.

Spruijt (1931) described a male Dutch Cropper pigeon, mosaic for plumage structure: most of the plumage was "silky", only a few groups of normal feathers occurring. Mated with a sister, the bird produced only normal young, typical of the breed. Hollander and Cole (1940) suggest that somatic mutation from normal to the known dominant "silky" factor may have been responsible, but a different, recessive, factor could also be invoked.

Before leaving sectorial mosaics in pigeons, we may note that patchy mosaicism is common with two sex-linked dominant color factors (in addition to ash-red, above): "almond", in females and heterozygous males, and "faded", in homozygous males. Since these effects seem to be merely an extension of variegation, they will not be treated further here.

In the budgerigar or shell parakeet (*Melopsittacus undulatus*), at least eighteen mosaics are known. Crew and Lamy (1935) reviewed seventeen of them, all except one being "half-siders." Each specimen was blue on one side (patchy in the exception), and green (wild type) or related color on the other side. No obvious size asymmetry was reported, and the sexes were about equally represented. The blue side was the right in twelve cases. Very little or no pedigree or breeding-test information is available, but Crew and Lamy assumed that all were initially heterozygous, the dominant green allele of the blue factor having been lost on the one side at the first cleavage division. Another factor, "dark", linked in inheritance with blue and green, was also involved in some of these birds, and it also appeared to be lost along with green. Therefore the authors concluded that the entire chromosome was lost. It is strange that no other chromosome seems inclined to such misbehavior.

Steiner (1938) reported a mosaic of related character, but quite unique. Its right side was white, the left mottled white and yellow (see Fig. 2). Many of the feathers of the left side were mosaic, striped longitudinally. When these were plucked, the succeeding feathers had exactly the same patterns. This bird was a male; one of its parents was white, the other yellow. Crossed with a white, the mosaic produced eight young, all white, and mated with one of his daughters he again produced only whites. The genetic explanation advanced by Crew and Lamy for the previous cases may be applied to this mosaic also, since white is the compound of the blue factor with yellow. Steiner suggests repeated loss of the chromosome carrying the non-blue factor, to account for the mottled effects.

A mosaic canary was reported by Crew and Munro (1938). This was a male of the Yorkshire variety; its right side was yellow, the left buff, with median line boundary. Its father was yellow, the mother buff. The mosaic had been a large nestling from a very large egg. Some size asymmetry was noted, the bones of the buff side being about 4.3 per cent smaller than those on the yellow side. The bird was fertile, but no breeding-test information was given. Since it came from a large egg, one may suspect binucleate origin.

Looking back over these sectorial mosaics, one sees that no one explanation is adequate for all; many seem comparable with similar types found in other organisms, but a few seem to have no counterpart elsewhere. It is fruitless to argue much over the explanations at this stage, however, since critical evidence that would limit the possibilities sufficiently is usually lacking.

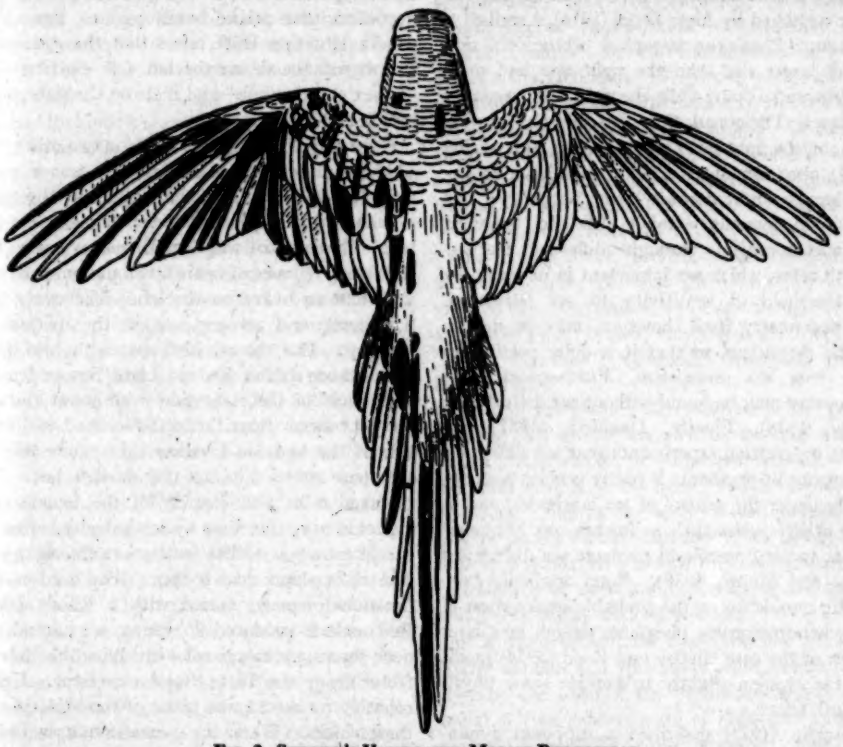

FIG. 2. STEINER'S VARIEGATED MOSAIC BUDGERIGAR

The areas shown in black represent yellow, the remainder of the plumage being white. Reproduced from Steiner (1938).

GYNANDROMORPHS

Although numerous reports of "hermaphroditic" or gynandromorphic birds are available, it is often difficult to decide whether they are true mosaics, because asymmetry is a normal condition in the bird reproductive system, and because the effects of sex hormones cloud the issue. In a genetic female embryo, the ovarian cortex and the oviduct of the right side usually degenerate; in a genetic male, these structures usually degenerate on both sides, but generally later on the left. However, sex hormones strongly influence the course of events, though the left-right gradient is still evident. Administration of estrogenic hormone to an embryo favors persistence of the ovarian cortex and the oviducts. A genetic male may thus artificially, and possibly also in nature, be feminized more or less, according to many studies (see Riddle and Dunham, 1942). On the

other hand, the rudimentary right gonad of a female bird may develop into a testis, producing sperms, if the left ovary is destroyed by disease or removed surgically (see Miller, 1938).

From such considerations, Riddle (1924) felt that no genetic (mosaic) explanation of sex mixtures was adequate in birds. He knew of no cases showing female characters on the right side and male on the left. It happens that the same is true for cases subsequently discovered, but one was overlooked by him: Bond (1914) described a pheasant (*Phasianus torquatus*) whose left side was of larger size than the right and had male plumage and a spur, while the right side was more feminine. The gonad of the left side was an ovotestis; on the right side there was no gonad. Lillie (1931) also discounted genetic mosaicism in explaining gynandromorphic birds; he pointed out that size asymmetry might lead to apparent gynandromorphism through different feather-growth rates, which are important in determining the threshold of sensitivity to sex hormones. Size asymmetry itself, however, may be due to genetic mosaicism, so that it is quite possible to have true sex mosaicism. Furthermore, size asymmetry may be found without sex disturbance (Crew, 1928). Finally, Danforth (1937) has shown by grafting experiments that sex difference in plumage of pheasants is partly genetic, and not wholly under the control of sex hormones, and in some other species such as finches, sex hormones appear to play no rôle in plumage sex differences (Crew and Munro, 1938). Bond originally gave genetic mosaicism as the probable explanation of his gynandromorphic pheasant, though in a later review of the case Huxley and Bond (1934) modified the opinion slightly to include some physiological effects.

Macklin (1923) described a supposed gynandromorph chicken. It was apparently of the Barred Plymouth Rock breed; there was very marked size asymmetry, the bones of the right side being larger than those of the left. On the right side a normal testis was found, while on the left there was an ovotestis. Not much else of genetic significance was known about the case.

The complex sectorial mosaic chicken reported by Vecchi (1936) has been discussed already above. In this case the left gonad was an ovotestis, the right a testis.

Hutt (1937) mentioned a case resembling Macklin's: a purebred Barred Plymouth Rock with larger bones on the right side, a testis on this side, and an ovary and oviduct on the left. The bird showed somewhat male behavior, and produced motile sperms, but these failed to fertilize eggs by artificial insemination. Hutt notes that the plumage and "shank" (foot) color was darker on the left side, and that the females of this breed are darker than the males. This sex difference is due to the sex-linked barring factor, which is homozygous in the males and has a greater lightening effect than where heterozygous. From this genetic situation Hutt infers that the gynandromorph was female on the left side—having only one sex chromosome—and male on the right, with two sex chromosomes.

Crew and Munro (1938) describe two other possibly gynandromorphic fowls. One was a purebred Rhode Island Red with bones of the right side about eleven per cent larger than those of the left. The left foot was of paler yellow color than the right. A normal testis was found on the right side, and an ovary on the left. The ovary was functional, and an egg was in the oviduct at autopsy. The second bird was a hybrid from male Rhode Island Red × Light Sussex female. The bones of the right side were about thirteen per cent larger than the left; the head and right side of the body had yellow skin, while the left side had white skin, to the median line. The plumage color was entirely of the female type expected from this cross by sex-linked inheritance, except for a few whitish feathers on the right side. The right shank had a spur. The bird was a functional female; mated with a Rhode Island Red male it produced 26 young, all normal and none showing plumage color involving the "Silver" factor from the Light Sussex ancestor. Unfortunately no record was made of the skin color of these chicks. When the gynandromorph died at the age of six years, it was found to have a large testis on the right side, with abundant spermatogenesis. As already noted in connection with sectorial mosaics in fowls, Crew and Munro explain these gynandromorphs by non-disjunction of the pair of chromosomes bearing the skin-color factors. They believe that the extra chromosome in the right side of a female embryo will induce the rudimentary gonad of that side to develop as a testis. In the case of the Rhode Island Red, which was presumably homozygous for the yellow skin factor, they suggest that non-disjunction produces skin-color mosaicism anyway—three yellow-

producing factors would be on the right side and only one on the left, so that the left side should be paler.

Crew and Munro (1938) also describe two Gouldian finches (*Gouldaeornis gouldiae*) with male coloration on the right side and female on the left. The bones of the right side were about two per cent larger than the left. Both specimens behaved as females and laid eggs. One was examined at death and showed no testicular structure. By means of other tests with birds of the species, the authors showed that sex hormones have no effect on the sexual differences in plumage color, so that the above mosaics must have a genetic origin.

Gynandromorphs have been most thoroughly studied in insects, where sex hormones and natural asymmetry of the gonads are not present to confuse genetic effects. Morgan and Bridges (1919), working with *Drosophila*, concluded that gynandromorphs resulted from loss of one sex chromosome of a pair, at the first cleavage division. Their use of sex-linked "marker" characters for following the chromosomes gave convincing evidence. An alternative theory for some cases is origin from a binucleate egg. This possibility was tested by L. V. Morgan (1929), and found to be unlikely. On the other hand, in the wasp, *Habrobracon*, gynandromorphs seem generally the result of double origin, according to much evidence obtained by Whiting (1928). Origin from a binucleate egg may be a possibility for some of the bird gynandromorphs; but the fowls described by Crew and Munro (1938) seem not explainable on this basis. The fortunate presence of such "marker" factors as skin color and plumage color is extremely helpful in following chromosome distributions and in ruling out some explanations.

The use of x-rays greatly increases the incidence of chromosome aberration, and by this means Patterson and Stone (1938) have produced many gynandromorphs in *Drosophila*. Loss of a sex chromosome or a large portion of one is the apparent basis for the sex mosaicism. Perhaps a similar technique will prove useful in studying gynandromorphism of birds. Another approach not yet attempted is to investigate the cytological constitutions of the differing parts of the mosaic birds. The chromosomal basis of normal sex determination in some species of birds has been fairly satisfactorily worked out (see Painter and Cole, 1943).

VARIEGATED CONDITIONS

Flecking, ticking, and mottling or harlequin effects are known to occur with some predictability in certain varieties and in certain crosses in chickens, turkeys, pigeons, ducks, and perhaps geese. The condition may even be responsible for the common name of a variety. Such crazy-quilt effects were distressing to Whitman, and gave rise to the following outburst (1919, vol. 2, p. 4):

"Nothing in the experience of breeders is more certain than that long-continued, promiscuous intermixing of stocks leads to instability and chaotic confusion in the transmission of characters. Characters are thus, as it were, churned up until their typical distribution in the developing organism is more or less deranged. Of course, chance results are then conspicuous, and laws are masked under distortions. Mixture is random, characters are placed in unnatural relations, broken up, and scattered as if sprinkled from a pepper-box. . . . Such conditions are graphically pictured in the colors of the thoroughly mongrelized domestic pigeon, and even in some of the so-called 'pure' breeds, described as 'mottled,' 'mealy,' 'grizzled,' 'splashed,' 'spangled,' 'wellbroken,' etc."

Most of these conditions referred to by Whitman, as well as the less obvious flecking, are so similar in appearance to variegation in plants that the term will be used here. Extensive studies have been made on the basis for variegation, not only in plants but in such insects as *Drosophila*, and some acquaintance with this background information is of great value in gaining an understanding of the conditions in birds.

It is often difficult to draw the line between patchy mosaics and variegation, and as might be expected the basis of the conditions is generally similar. Two general sorts of bases are known: somatic segregation, and somatic mutation. These terms are used in a loose way, as the precise details are often varied. At any rate, with variegation there is almost always an inherited predisposition or instability, which can be assigned to Mendelian factors or to chromosome anomalies.

Several different mechanisms of somatic segregation have been demonstrated or deduced. In maize, the well known "calico" variegation of seed pericarp has been studied by several investigators; Eyster (1925, 1927, 1934) has noted that in homozygous plants paired stripes of divergent

color are often found. From this and much other information, he reasons that in these types of maize a compound gene exists, made up of several units ("plus" and "minus") of opposing types, and that the compound may not divide equally at mitosis, so that the two daughter cells obtain different amounts.

Stern (1936) made an elaborate analysis of variegated conditions in *Drosophila* induced by the "Minute" factors, which somehow promote chromosome aberrations. He found that in heterozygous flies the component characters would appear in spots—usually paired—of divergent homozygous phenotype. From evidence with linked genes, Stern showed that a process occurred in somatic cells that segregated factors very much like meiosis, and involved crossing over.

Other types of variegation in maize than that studied by Eyster have their basis in chromosome anomalies: Beadle (1932) reported a mutant type characterized by faults and stripes of defective tissue, due to complications and aberrations at mitosis, the chromosomes tending to tangle ("stickiness"). McClintock (1938, 1942) notes the occurrence of variegation in plants having ring-shaped chromosomes, or chromosomes with terminal reverse-repeat duplications. Such chromosomes at mitosis occasionally produce joined daughter chromosomes with two spindle-fiber attachments (dicentric). As the cell divides, the dicentric chromosomes are stretched between opposite poles, and generally break, the resulting fragments usually being unequal. A progressive segregation process may follow, with marked variegation, scarring, and irregular growth. Rhoades (1940) has obtained somewhat similar effects in plants having another unusual chromosome structure —a completely terminal spindle-fiber attachment (telocentric); this condition seems to be unstable.

Somatic mutation has been called on to explain many cases of variegation in plants, especially in flowers. The variegated types have generally been found to differ from normal in being homozygous for a recessive gene, and the speckles seem to be points of reverse mutation to the normal dominant condition. Therefore the variegated types are considered the effect of a "labile" or highly mutable gene. Reviews of work on such types are given by Stubbe (1933), Demerec (1935), and to some extent by Chittenden (1927) and Showalter (1934). Rhoades (1938) found that a mutant factor in maize could be induced to become labile when combined with a certain other mutant, but was otherwise stable.

A remarkable type of variegation has been found occasionally among descendants of irradiated spermatozoa of *Drosophila*. Muller (1930) called it "eversporting displacement," since all examples were associated with chromosome translocations or inversions. At present the condition is generally referred to as mottling. Patterson (1932) believed that the chromosome rearrangement in such types was unstable, and cytological evidence was advanced in support of the idea. Apparently this could not be verified in other laboratories. Stern (1935) suggested that a duplicated piece of a chromosome attached as a branch to the chromosome might explain mottling, but such a structure has not been found. Stern also pointed out that the rearrangements generally involved the spindle-fiber region of the chromosomes; this region is cytologically distinct, being known as heterochromatic, and in common with the Y chromosome of *Drosophila*, seems to be mainly "inert" or lacking genes. Gowen and Gay (1933) had observed that addition of a Y chromosome to a mottled-type female fly's constitution would result in almost complete reversion to wild-type appearance. These facts led Schultz (1936) to another (now abandoned) theory: that non-specific attraction and merging of heterochromatin at mitosis might produce ring configurations which would tend to drop out fragments, and thus give mottling.

Mottling in *Drosophila* is now almost a synonym of "position effect." In Dobzhansky's (1936) review of such effects, it is pointed out that instability of phenotype is common for factors located at or near a point of breakage or rearrangement. The dominance of wild-type factors may be weakened or lost. In the studies of Demerec (1939, 1940) and his associates (Kaufmann, 1942; Sutton, 1940a, b; Hinton and Atwood, 1940), mottling has always been found to involve rearrangements with heterochromatic regions, and factors at some distance from the point of break may show effects. The studies of Morgan, Schultz, Bridges and Curry (1938) and Morgan, Schultz and Curry (1939–1941) have attempted to elucidate the relation of mottling to heterochromatin. The following notes seem specially significant: (1) Low temperatures, which accentuate the position effects, produce an increase in nucleic acid content of euchromatic regions transposed into heterochromatic regions. (2) Loss of a re-

gion of heterochromatin (not necessarily the one involved in the rearrangement) accentuates the position effect. These investigators believe that position effects result from a sort of inactivation of the euchromatic material, by conversion into heterochromatin, with large deposits of nucleic acid; reactivation should give mottling.

At any rate, the consequences of the mottling mechanism are much like somatic mutation, as in variegated flowers; however, some types are transmitted as dominant to normal, so that mutation is toward the recessive; and mutation may be of several different grades (Demerec and Slyzinska, 1937).

It should be obvious from the variety of possible causes for variegation that the analysis of examples in birds may run into great difficulties, even though a superficial control may be attained. I shall take up the several species in turn.

The earliest scientific note known to me on variegated conditions in birds is that of Hadley (1913), who was studying crosses of the White Leghorn breed of fowls. These generally are white with flecks or speckles of dark color. He states that the flecking is scanty in F_1 of both sexes from White Leghorn cock × White Silkie hen, while the reciprocal cross gave abundant flecking. No other study of this point has been made.

Serebrovsky (1926) observed that flecking is commonly found in many sorts of crossbred fowls, but also in purebred females of the Barred Plymouth Rock breed and in White Andalusians (homozygous for the "blue" factor). In chickens having the "blue" factor, Serebrovsky says, "Among the blue feathers we can always find parts of feathers and even whole feathers of an intense black color. . . . The same occurrence is to be observed with the . . . homozygotes, and it is here even more striking. The exceptional feathers are not black among blue ones, but blue among dirty white ones." It should be noted here that the presence of black flecks in blue chickens was overlooked by Lippincott (1921); as a consequence his theory of the inheritance of this color type was based on the misconception that "splashing" is limited to the homozygote. Serebrovsky accounted for the flecking here and also with the dominant white factor (White Leghorn crosses) by assuming that the dominant factor is "lost" in small areas. He might equally well have considered these dominant factors labile, reverting to recessive wild type.

In the Barred Plymouth Rock breed Serebrovsky encountered a slightly different situation. This breed's coloration differs from the junglefowl type mainly by reason of three dominant factors: two sex-linked, one known as "Bar" and the other as "Silver"; and a third not sex-linked, known as "Black." We may ignore the last factor, since it seems to play no part in the aberrations. When homozygous males are examined, no flecking is to be found, as a rule (very rarely a black fleck occurs); females however cannot be homozygous, since they have but one sex chromosome and must be termed hemizygous, and in their plumage black flecks and entire black feathers are found rather commonly. When Serebrovsky crossed this breed with others lacking Bar and Silver, the heterozygous Bar Silver sons showed many flecks and exceptional feathers. These fell into three classes: (1) feathers showing Silver but not Bar—seldom; (2) feathers showing Bar but not Silver—seldom; and (3) feathers showing neither—frequent. These class frequencies were greatly altered, however, when he made up the heterozygous males so that the Bar and the Silver factors came from different parents and thus did not occupy the same chromosome—the parents being Bar (without Silver) × Silver (without Bar). Class (1) exceptional feathers were most prevalent here; class (2) was seldom, and (3) never observed. From these striking results he concluded that "in the development of exceptional feathers there would appear to be some form of somatic segregation whereby some feathers get one set of genes and other feathers another set; and *as in the normal segregation* the genes . . . , localized in the same chromosome, show linkage, this same linkage is also to be found in the 'somatic segregation'." But he qualifies this statement with the opinion that crossing over is less frequent in the somatic cells than in the germ cells.

Hertwig and Rittershaus (1929) also crossed Barred Plymouth Rock fowls with other breeds lacking the Bar and Silver factors, particularly with the Orloff and the Gold-spangled Hamburg. The F_1 males all showed exceptional feathers, but much more plentifully in the Hamburg crosses. In contrast to Serebrovsky's findings, these authors state that the majority of the exceptional feathers showed loss of the Bar effect but not of the Silver, and the same result was found in females. Therefore the theory of somatic segregation was rejected; the authors concluded that if loss is an acceptable explanation, then that region of the

sex chromosome carrying the Bar locus is peculiarly subject to such loss, and not the chromosome as a whole. But the Silver factor is not nearly so stable as Hertwig and Rittershaus imply. MacArthur (1933) says: "Though silver is clearly dominant over gold, practically every *S s* [heterozygous] male bore numerous feathers partly gold, due probably to somatic segregation as described by Serebrovsky." Further study of the whole matter with more refined methods seems required.

Hertwig and Rittershaus noted that plucking of the feathers did not increase the incidence of exceptionals. Juhn (1933) made a further study of this point, by plucking and comparing feathers successively regenerated in particular follicles. She used capons from the cross of Barred Plymouth Rock × Brown Leghorn (lacking the Bar and Silver factors). Practically no correlation was found between the aspect of any given feather and that of its successor. Montalenti (1934) used purebred Barred Plymouth Rock hens; he found similar unpredictability in succession, except when entire feathers were exceptional (black), in which case the regenerated feathers were also of this sort. Danforth (1937) found quite comparable results in succession of feathers with mosaicism induced by skin grafting. Juhn believed that her evidence eliminated any genetic-mosaic explanation for exceptional feathers, and therefore suggested a sort of physiologically controlled reversal of dominance, or suppression of the effects of the color factors inherited from the Barred Plymouth Rock. This idea seems negated by the more recent evidence on the migratory activities and self-determination of melanophore cells, which control pigmentation. The experiments of Foulks (1943) are most pertinent in this connection. The irregularity of color type in feather succession must be attributed to the moving of melanophores, but the exceptional colors are best explained as the result of genetic changes in some of the melanophores, or as mosaicism.

Another type of chicken with variegation is the "mottled," "fig-pudding," "almond," or "spangled" color variety of the Old English Game fowl. Colored illustrations are given by Wright (1902) and by Johnson and Brown (1904). White Games showing a few scattered colored feathers are also known, and may be the homozygote, but no studies of the inheritance of these colorations have been made, apparently. Other breeds showing possible indications of variegation are the Hamburg, studied by Landauer and Dunn (1930) and by Taylor (1932); the Houdan; and the Mille Fleur Bantam. All these show a certain amount of irregularity of pattern which may be attributable to mosaicism.

The turkey was among the first species of birds in which a study of variegation was undertaken. The known facts are set forth by Robertson (1925) in an abstract. There are two factors, both dominant to the wild-type bronze, which are accompanied by variegation: "Black," and "Blue." As in the chicken, the variegation consists of flecks, stripes, blotches, or even entire feathers in which the effect of the dominant factor seems to be lost. Only heterozygous turkeys show variegation. Robertson suggested somatic non-disjunction of chromosomes as a possible explanation.

"Blue" coloration accompanied by flecking in the heterozygote is also found in two species of domestic ducks, *Anas boschas* and *Cairina moschata*. Some comments on the genetics of these types are given by Jaap and Milby (1944).

The reviewer has observed some dark flecking in the whitish ganders of the Pilgrim variety of geese. The females are of different color—gray with some piebaldness. The genetic basis of the coloration in this type has not been analysed (Quinn, 1939).

Studies of flecking and exceptional feathers in pigeons have been reviewed to 1940 by Hollander and Cole, but several additions and revisions are now necessary. The present review is intended to be complete, but for further details and background information on the genetic factors involved the reader should consult Hollander and Cole (1940) and Levi (1941).

Flecking in pigeons was known to Darwin (1874), and interested him particularly because he knew of it only in males. Apparently he was dealing with the dominant "ash-red" color factor, which was shown by Cole and Kelley (1919) to be sex-linked and to be accompanied by flecks. Steele (1926) investigated the sex difference in the flecking, and concluded that females do show some flecks, though less often, fewer, and more brownish in color than those of males. The flecks in males are ordinarily black-pigmented (wild-type), but Hawkins (1931) found that only brown flecks were to be found in ash-red males heterozygous for a sex-linked recessive brown color, and linkage tests indicated that brown is allelic to ash-red. Hawkins concluded that flecking was simply a consequence of heterozygosis. This explanation, reminiscent of Whitman, becomes tenuous when we consider flecking in ash-red females, which

have only one sex chromosome and are therefore hemizygous rather than heterozygous. Hollander and Cole (1940) state that the flecks found in ash-red females are always brown, but very rarely I have found exceptions to the rule; Mrs. R. Frisch has shown me a large blackish fleck in a female's tail feather. In connection with the sex differences of flecking with ash-red, it is desirable to recall that the sectorial mosaics involving the ash-red factor were all males. It is quite possible that the same sort of genetic change underlies both types of mosaicism here, when occurring earlier in ontogeny producing the sectorial effects.

A second well known coloration accompanied by variegation in pigeons is known by the name "almond" in the Tumbler breed, and "magnani" in the Modena breed. Many breeders have discussed this coloration, with the general conclusion that the flecking increases with each year's moult, and is more pronounced in males than females. Ghigi (1908) stressed the sex difference, with observations on Modenas. Wriedt and Christie (1925) first investigated the inheritance of the character, in Tumblers, and showed that it is sex-linked and dominant to wild type. They apparently did not suspect genetic change in the soma, but considered the variegation part of the almond character. Dr. H. W. Feldman (unpublished data, 1934) initiated a study of the relationship between almond and ash-red. Heterozygous males were of light almond color, but their flecking was ash-red instead of wild type. In brief linkage tests no crossing over was observed between the factors. Feldman also noted that almond males with pronounced flecking were never homozygous; almond × almond matings produced some white offspring, which probably were the homozygous phenotype, according to later studies. Mr. R. E. Gilbert has found that such white males may develop a small amount of flecking (personal communication, 1940).

A third dominant sex-linked coloration accompanied by flecking has recently been discovered and is named "faded." The first known pigeon of this type was a son of an almond female in Feldman's colony. By sex-linked inheritance the bird should have been almond, and breeding tests indicate that it is allelic to almond. Faded has also been found in a small percentage of White Carneau pigeons crossed with wild-type individuals of other breeds. When homozygous, the faded factor produces a whitish plumage with numerous faded flecks, but the heterozygous male and the female show only a slight flecking with wild type. This striking contrast is analogous to that in Andalusian fowls, as discussed above, and its practical application has been described by Hollander (1942).

Hollander and Cole (1940) produced male pigeons heterozygous for almond and brown, and noted the occurrence of both brown and wild-type flecks in the plumage. From this fact, and others, it was tentatively concluded that brown, wild type, ash-red, faded, and almond constitute an allelic series, in ascending order of dominance, and that the three upper members are unstable, or labile genes, tending to mutate to one or another of the more recessive alleles. Hollander (1942) further suggested that the direction of this mutation is in part governed by which of the other alleles is present—i.e., mutation is toward the latter type. However, this idea was retracted (1943) because of the discovery of a crossover between the assumed alleles brown and faded. The crossover is a male combining the phenotypes of both factors, and it is homozygous for brown and heterozygous for faded by progeny test. He has two sons which are homozygous for faded and heterozygous for brown; their plumage is whitish with two types of flecks: faded and faded brown. The original assumption of a series of five alleles is therefore untenable, and now two closely linked series are postulated: brown, wild type, and ash-red in one, and wild type, faded, and almond in the other. Further discussion of the flecking with these factors will be given below.

In addition to the sex-linked group of factors, at least two autosomal dominant color factors in the pigeon are accompanied by flecking. One of these is "Indigo," described by Levi (1941); a small amount of flecking can be found in most heterozygous individuals. The second is "Grizzle," which when heterozygous produces a coarse whitening of the plumage, like hoar-frost. Occasional feathers of such birds, particularly around the head and neck, are either completely wild type or completely white. Homozygous birds are much more whitened than the heterozygote, and off-color feathers are not clearly evident. The variegation with grizzle has not been studied. Wriedt and Christie (1929) have described several grizzle-like conditions found regularly in certain breeds, but differing from grizzle in their tendency to "whiten" with maturity. The names of some of these types are suggestive: "tigered," in Norwegian Tumblers; "mottled," "rose-wing," or "white-

side," in red Danish Tumblers; and "whitened" in Danish Branders. It is possible, but unlikely, that the same grizzle factor is involved in all these types. Some evidence is available on a "tigered" condition derived from White Carneau pigeons in my studies, indicating that it is not allelic with the grizzle factor. Some specimens in this family rival almond in the abundance of variegation shown, but the frequent presence of the factor for piebaldness is confusing. It seems clear that investigation of such types may yield

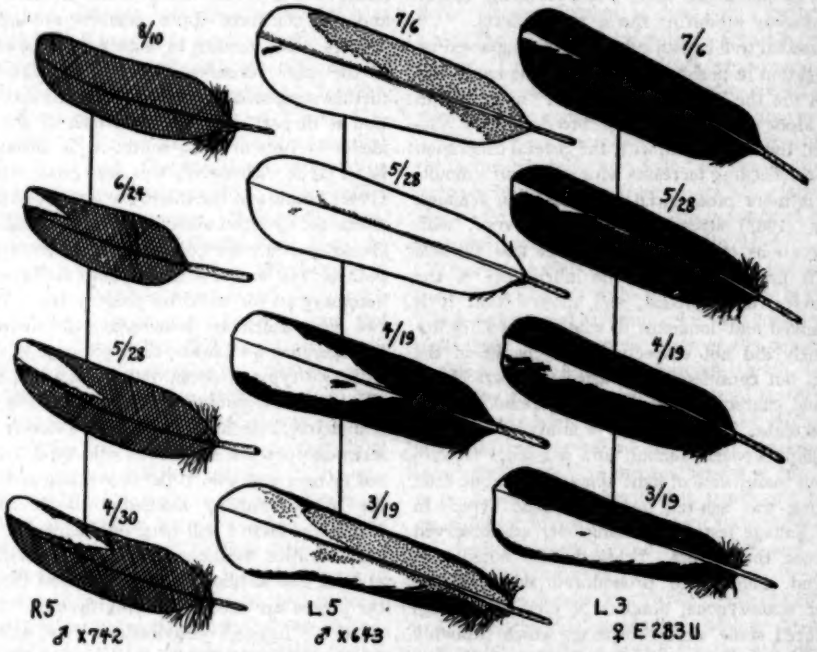

FIG. 3. EXAMPLES OF FEATHER SUCCESSION IN ALMOND PIGEONS

Each vertical column consists of four successive feathers grown from a single follicle; dates of plucking are given above the feathers. Female E283U (right column) is the mother of the two males, which were sired by a homozygous brown. Solid black = wild-type (black) pigmentation; cross-hatching = "faded" coloration; stippling = brown; and white = basic almond effect (whitish). Sketched from the author's collection.

significant and interesting additional information on variegation, especially since there seem to be decided differences in the genetic changes as compared with ordinary flecking.

If we may now return to flecking with the sex-linked factors, and ignore the autosomal types like grizzle, since so little is known about them, let us consider some additional details. The abundance or scarcity of flecking must be taken up—there are not only sex differences in this, but also age differences and individual differences, often very marked. Very little study has been given to the basis for such differences. Hawkins (1931) compared feathers of ash-red males before and after castration, to see whether male hormone had any effect; no significant change in fleck frequency was found. Hollander and Cole (1940) point out that the element of chance seems to play a large part in flecking; small flecks are almost never duplicated in regenerating feathers, and even where half or more of a feather is altered, the succeeding feather may show only an approximately similar appearance (see fig. 3). Most of this irregular and unpredictable behavior is readily explainable on the assumption that the variegation is a melanophore effect: some melanophores become genetically different and their migratory movements result in a variety of patterns.

The essential problem that remains seems to be the nature of the genetic change which is responsible for flecking. It seems possible to eliminate certain conceivable explanations. First, heterozygosis is not necessary, although it may permit

phenotypic *expression* of the genetic change more readily than in the homozygote (e.g., ash-red). Second, since ash-red females have brown flecks, while almond females do not, and since females have only one sex chromosome, we can be sure that chromosomal loss or non-disjunction is not the correct explanation. Third, since almond males heterozygous for brown show brown flecks as well as other colors, and since almond is not allelic to brown, as shown by crossing over, simple gene mutation will not cover the facts. Fourth, somatic crossing over and segregation, impossible in the female, seem unlikely even in the almond male heterozygous for brown; these factors appear to be very closely linked in the germ cells, yet the "crossover" type of flecking (wild type) is relatively frequent, and furthermore, there is no indication of "twin-spots." Fifth, an initially aberrant chromosome structure, such as translocation, ring shape, or reverse-repeat duplication seems unlikely because reproduction is normal—a higher embryonic mortality would be expected. Also, for the last two possibilities, one might expect somatic structural faulting, scarring, and asymmetry, and these are not observed.

Variegation associated with position effect is not eliminated as a possible explanation so far, although two facts reduce its probability: since embryonic mortality is normal, the postulated rearrangement is not likely to be a translocation but more probably an inversion of a segment. And since meiotic crossing over between these factors and another sex-linked factor, "dilution," is frequent, the inversion would have to be small. In fig. 4 a diagram is given of a possible explanation on the basis of small inversions involving heterochromatin. The variegation might then be considered analogous to that with position effects in *Drosophila*, but the real nature of the genetic change involved remains enigmatic.

Cole and Finley (1942) have tried to get at the mechanism of flecking in ash-red pigeons by means of x-rays. They plucked feathers from the wings of males heterozygous for wild type, and immediately subjected one wing to irradiation (750 r to 1000 r units), the other wing serving as the control. A very marked increase of flecking appeared in the regenerated feathers of the treated wings, and three successive pluckings without further treatment showed no decrease. The success of this experiment was attributed to increased mutation of the ash-red factor to a recessive allele under the influence of the x-rays; but for a particular gene to mutate so frequently with such a low dosage seems very improbable. X-rays are very effective in producing chromosome rearrangements, however, and Kaufmann (1942) has shown that in *Drosophila* "reverse mutation" frequently is obtained by x-raying a type involving a position effect. The analogy here is encouraging, and the use of irradiation as a tool in analysing variegation in birds will undoubtedly be very informative in the future. Other agents which may be tried include heat and drugs, since some physiological influence seems to be indicated in age and individual differences in flecking.

It may seem significant that all the variegated conditions known in birds involve pigmentation rather than structural characters. One might conclude that some condition in the melanophore cells predisposes genetic change of the pigmentation factors. But in "almond" pigeons genetic change has occurred in the germ cells also, in at least three instances. It is my opinion that the very conspicuousness of color variegation has been the chief reason that it seems the only sort—we are blinded to the occurrence of structural "mottling" as yet.

FIG. 4. DIAGRAMS OF THE SEX CHROMOSOME OF THE PIGEON TO ILLUSTRATE HYPOTHETICAL REARRANGEMENTS WHICH MIGHT ACCOUNT FOR VARIEGATION WITH ASH-RED AND ALMOND TYPES AS POSITION-EFFECT MOTTLING, BY ANALOGY WITH CASES IN DROSOPHILA

The approximate loci of two recessive sex-linked colorations, brown (b) and dilution (d), are represented by spots. Stippling represents the assumed position of heterochromatin.

PIEBALDNESS AND OTHER ERRATIC CONDITIONS

Piebald varieties occur in almost every domestic species of bird except probably turkeys and chickens. The condition has a hereditary basis as a rule, but the variation is often so extreme that genetic analysis has not been completed. Asymmetry is very common, though rarely of high degree. Bond (1912) observed that heterochromia of the iris often accompanies piebaldness; his breeding-test results reveal some of the difficulties

in genetic study of the "trait." Cole (1914) also studied the inheritance of piebaldness and heterochromia in pigeons with similar results—the condition was too complex for final conclusions. He illustrates a common type of heterochromia in pigeons: one eye with bright-pigmented iris, the other iris black (no bright pigment). Such asymmetry is suggestive of mosaicism, but another possibility will be shown below.

Pigeons exhibit a remarkable array of piebald patterns that have been fairly well "fixed" by selective breeding. Numerous fanciers over long periods of years—even centuries—have devoted much attention to these ends. Kuhn and Kuhn (1932) have surveyed the types, and photographs of many are given by Levi (1941). Perhaps the most notable are the "Magpie," the "Nun," the "Baldhead," the "Turbit," and the "Spot." In these pure breeds variation is at a minimum, but in crosses and mongrels the condition well merits the common descriptive name "splashed." The "White-side Tumbler" is unusual in showing little or no white plumage in youth, and in some other varieties the amount of white increases with successive moults (Wriedt and Christie, 1929).

Studies of piebaldness in other species of birds are few. Jaap (1933) distinguishes several genetically distinct types in ducks. Crew and Lamy (1935) suggest that the pied condition in the parakeet may be due to somatic change, since "all the recorded instances of this condition are explicable on the assumption that the yellow chromosome is eliminated late in development."

It is remarkable that the chicken, which is abundantly variable in most respects, has no piebald varieties. On the other hand, white feathers seem unusually easy to induce in chickens by traumatic or other physiological means; the mere plucking of large feathers may result in failure of pigmentation of the successors.

Piebaldness is essentially the co-existence of pigmented and non-pigmented areas of integument. Since absence of melanophores (pigment cells) or their failure to function is the basis for whiteness of skin and plumage, and since the melanophores do not originate *in situ* or even remain indefinitely in one place, but migrate from the neural crest region of the embryo (Dorris, 1939; Watterson, 1942; and others), genetic mosaicism is difficult to prove in piebaldness. Very likely there is some hindrance to the migration of melanophores in some regions of prospectively pied embryos, or some other reason for failure of melanophores to establish residence in such regions. Grafting experiments will be of value in clearing up these questions.

A connection between the occurrence of color mosaicism and the presence of piebaldness has been suggested for mammals by Feldman (1935) and previous investigators. The prevalence of piebaldness in pigeons with sectorial mosaicism may also seem significant. It is not invariable, however, and piebaldness is so common among pigeons that coincidence is very probable. No relation has been observed between piebaldness and variegation, except possibly with the "grizzle" conditions.

Polydactyly, a dominant character in fowls, is notably inclined to asymmetry, but more so in crosses than in purebreds. Bond (1926) crossed Houdans (polydactyl) to normal Andalusians. Variation of the polydactyly in the descendants was very great, and apparently not related to the plumage colors (blue, etc.) involved. Punnett and Pease (1929) used Houdan, Dorking, and Silkie fowls (all polydactyl) with normal Brown Leghorns and a few others. In each cross certain families had a high proportion of asymmetrical and also apparently normal young, so that a genetic modifier was postulated, probably being introduced by the normal breeds, and tending to suppress the character. Genetic mosaicism may exist in asymmetrical specimens, but another explanation seems quite likely: Sturkie (1942) has shown that environmental conditions during early embryonic stages may decisively affect the differentiation of the feet in genetically polydactyl individuals, even to suppression of the trait.

Bond (1914) noted asymmetry of spur development in a gynandromorphic pheasant. Apparently true genetic mosaicism was responsible (see section on gynandromorphs). He also studied spur asymmetry occurring spontaneously in several Brown Leghorn hens (1937). Normal hens show only a tiny rudiment of a spur, but these hens each had one spur of considerable size. In crosses with an unrelated Brown Leghorn cock and a Houdan, the asymmetry was transmitted to a fairly high proportion of the female offspring, and in addition, some daughters had symmetrically male-like spurs. In connection with the spur enlargement, Bond notes that the lower leg bones were also larger than normal. Whether the asymmetry here is due to mosaicism can not be decided at present.

Other sorts of erratic development which may be

considered as possibly mosaic are often encountered. For example, a pigeon with a tail feather growing out of the middle of the back has been studied by Dr. L. J. Cole (unpublished). No inheritance was obtained. One might account for the condition by assuming that an embryonic "transposition," equivalent to an autoplastic graft, had occurred. The permanence of feather-type differentiation in grafts has been demonstrated by Danforth (1932), Lillie and Wang (1941, 1943), and Rawles (1944).

CONCLUSIONS

From this review it is clear that we have only reached the threshold of a real understanding of spontaneous mosaicism in birds. The field seems a fertile one for further research, and it is to be hoped that students will make the most of rare opportunities, such as half-and-half specimens. As much information about such cases as can be secured is needed to deduce their origin: analysis of ancestry, progeny tests, and complete records of phenotype. As yet there is no good evidence for origin from a binucleate egg, though it may have occurred. There is fair evidence for nondisjunction of a chromosome in several cases where the pedigree is informative, or other genetic evidence is available.

In addition to deductions from genetics, we find that grafting has afforded considerable insight into natural mosaicism. Probably the greatest difficulty to the comprehension of the nature of color mosaic conditions has been the erratic nature of the patterns and the rather unpredictable results in feather regeneration. The clue to the mystery came from grafting studies, which showed that the pigment cells (melanophores) tend to wander. Color mosaicism not involving *melanin* pigments is more comparable to structural mosaicism, giving more logical patterns and repetition in regeneration. Examples of the latter type are afforded by Steiner's parakeet and the pigeons mosaic for the "spread" *pattern*.

Variegation is perhaps the most intriguing category of all types of mosaic effects, and the most complicated. Although many of the difficulties of interpreting the phenomenon have been cleared up, and we feel certain that genetic change in the soma is involved, the central problem remains: What is the nature of the genetic change? If, as seems likely at present, "eversporting" associated with "position effect" is responsible, it will be the first instance of this phenomenon occurring naturally. If it is not the explanation, then an entirely novel state of affairs must exist, as compared with variegation in other forms of life.

The use of x-rays to produce mosaicism at will should greatly expand our possibilities. It may even furnish clues as to linkages between hereditary factors, and thereby speed up the tedious work of mapping chromosomes by breeding tests. Serebrovsky (1926) commented that by examining the types and frequencies of "exceptional feathers" occurring spontaneously in chickens, one can infer the genetic constitution of the birds almost as accurately as by a progeny test, at least for a number of color factors. Perhaps the genetics of the soma may eventually be as well elucidated as that of the germ line.

It seems fair to conclude that, although the precise mechanisms and ultimate causes of spontaneous genetic diversity of tissues are still rather nebulous, a fairly extensive and useful body of information has been accumulated. From this foundation we can expect to develop a far more complete perception of the processes of growth, differentiation, and the activities of genes and chromosomes. Instead of the chaos envisioned by earlier biologists, we begin to see a semblance of order and control. After so many years of contemptuous disregard, the motley fowl and the lopsided freak have achieved a special dignity.

LIST OF LITERATURE

ASMUNDSON, V. S. 1937. Note on a bronze-Bourbon red mosaic [turkey]. *J. Genet.*, 35: 25–30.

BEADLE, G. W. 1932. A gene for sticky chromosomes in *Zea mays*. *Z. i. Abst.- Vererb.*, 63: 195–217.

BOND, C. J. 1912. On heterochromia iridis in man and animals from the genetic point of view. *J. Genet.*, 2: 99–129.

——. 1914. On a case of unilateral development of secondary male characters in a pheasant, with remarks on the influence of hormones on the production of secondary sex characters. *J. Genet.*, 3: 205–216.

——. 1926. Further observations on polydactyly and heterodactyly in fowls. *J. Genet.*, 16: 253–256.

——. 1937. On asymmetric spur development in fowls. *J. Genet.*, 34: 229–235.

CASTLE, W. E. 1935. The Brahma-Plymouth Rock mosaic. *J. Hered.*, 26: 66.

CHITTENDEN, R. J. 1927. Vegetative segregation. *Bibl. Genetica*, 3: 355–463.

COLE, L. J. 1914. Studies on inheritance in pigeons I. Hereditary relations of the principal colors. *Rhode Island St. Coll. Agric. Exp. Sta. Bull.* 158, 313–380.

——, and H. E. FINLEY. 1942. The production of somatic mutations in the pigeon with X-rays. *Genetics*, 27: 138 (Abstract).

——, and F. J. KELLEY. 1919. Studies on inheritance in pigeons III. Description and linkage relations of two sex-linked characters. *Genetics*, 4: 183–203.

CREW, F. A. E. 1928. A case of lateral asymmetry in the domestic fowl. *J. Genet.*, 20: 179–186.

——. 1932. A case of leg-colour asymmetry in the fowl. *J. Genet.*, 25: 359–365.

——, and R. LAMY. 1935. Autosomal colour mosaics in the budgerigar. *J. Genet.*, 30: 233–241.

——, and ——. 1939. Mosaicism in *Drosophila pseudo-obscura*. *J. Genet.*, 37: 211–228.

——, and S. S. Munro. 1938. Gynandromorphism and lateral asymmetry in birds. *Proc. Roy. Soc. Edinb.*, 58: 114–134.

——, and ——. 1939. Lateral asymmetry in the fowl. *Proc. VII World's Poultry Congr. Cleveland*, 61–64.

DANFORTH, C. H. 1928. Skin transplantation in ducks and pigeons. *Proc. Soc. exp. Biol., N. Y.*, 25: 717.

——. 1929. Genetic and metabolic sex differences: the manifestation of a sex-linked trait following skin transplantation. *J. Hered.*, 20: 319–322.

——. 1932. Genetics of sexual dimorphism in plumage. *Proc. VI Intern. Congr. Genet. Ithaca*, 2: 34–36.

——. 1935. Genetic mosaics in the feathers of the common fowl. *Trans. Dynam. Develop.* (Russ.), 10: 339–344.

——. 1937. Artificial gynandromorphism of plumage in Phasianus. *J. Genet.*, 34: 497–506.

——. 1937. An experimental study of plumage in Reeves pheasants. *J. exp. Zool.*, 77: 1–11.

——. 1937. Pigment cells in heterogeneous feathers. *Anat. Rec.*, 68: 461–467.

——. 1939. Direct control of avian color pattern by the pigmentoblasts. *J. Hered.*, 30: 173–176.

——, and F. FOSTER. 1929. Skin transplanatation as a means of studying genetic and endocrine factors in the fowl. *J. exp. Zool.*, 52: 443–470.

DARWIN, C. 1874. The Descent of Man, and Selection in Relation to Sex. (Second ed.) *Philadelphia:* David McKay.

DEMEREC, M. 1935. Unstable genes. *Bot. Rev.*, 1: 233–248.

——. 1939. The nature of the changes in the white-Notch region of the X-chromosome of *Drosophila melanogaster*. *Proc. VII Intern. Genet. Congr. Edinb.*, 99–103.

——. 1940. Genetic behavior of euchromatic segments inserted into heterochromatin. *Genetics*, 25: 618–627.

——, B. P. KAUFMANN, and E. SUTTON. 1938-9. The gene. *Carnegie Inst. Wash. Yearbk.*, 38: 185–191.

DEMEREC, M., and H. SLIZYNSKA. 1937. Mottled white 258-18 of *Drosophila melanogaster*. *Genetics*, 22: 641–649.

DOBZHANSKY, T. 1936. Position effects on genes. *Biol. Rev.*, 11: 364–384.

DORRIS, F. 1939. The production of pigment by chick neural crest in grafts to the 3-day limb bud. *J. exp. Zool.*, 80: 315–345.

EASTLICK, H. L. 1939. The point of origin of the melanophores in chick embryos as shown by means of limb bud transplants. *J. exp. Zool.*, 82: 131–157.

——. 1941. Manifestations of incompatibility in limb grafts made between bird embryos of different species. *Physiol. Zool.*, 14: 136–144.

EYSTER, W. H. 1925. Mosaic pericarp in maize. *Genetics*, 10: 179–196.

——. 1927. The mechanism of variegations. *Proc. V Intern. Congr. Genet. Berlin*, 666–686.

——. 1934. Genetics of *Zea mays*. *Bibl. Genetica*, 11: 191–392.

FELDMAN, H. W. 1935. A mosaic (dark-eyed intense—pink-eyed dilute) coat colour of the house mouse. *J. Genet.*, 30: 383–388.

FOULKS, J. G. 1943. An analysis of the source of melanophores in regenerating feathers. *Physiol. Zool.*, 16: 351–380.

GAYER, K., and V. HAMBURGER. 1943. The developmental potencies of eye primordia of homozygous Creeper chick embryos tested by orthotopic transplantation. *J. exp. Zool.*, 93: 147–183.

GHIGI, A. 1908. Sviluppo e comparsa di caratteri sessuli secondari in alcuni ucelli. Nota letta alla R. Acad. Sci., Ist. Bologna, 15 Mar., 3–23.

GOLDSCHMIDT, R., and K. KATSUKI. 1931. Vierte Mitteilung über erblichen Gynandromorphismus. *Biol. Zbl.*, 51: 58–74.

GOWEN, J. W., and E. H. GAY. 1933. Eversporting as a function of the Y-chromosome in *Drosophila melanogaster*. *Proc. Nat. Acad. Sci. Wash.*, 19: 122–126.

——, and ——. 1933. Effect of temperature on eversporting eye color in *Drosophila melanogaster*. *Science* 77: 312.

HADLEY, P. B. 1913. Studies on inheritance in poultry I. The constitution of the White Leghorn breed. *Rhode Island St. Coll. Agric. Exp. Sta. Bull.* 155: 151–216.

HAMBURGER, V. 1941. Transplantation of limb primordia of homozygous and heterozygous chondrodystrophic ("Creeper") chick embryos. *Physiol. Zool.*, 14: 355–365.

HAMILTON, H. L. 1940. A study of the physiological properties of melanophores with special reference to their role in feather coloration. *Anat. Rec.*, 78: 525–547.

HAWKINS, L. E. 1931. Studies on inheritance in pigeons X. Relation of chocolate to black and dominant red. *Genetics*, 16: 547–573.

HERTWIG, P., and T. RITTERSHAUS. 1929. Ueber Fehlfedern bei gesperberten Hühnern. *Arch. Geflügelk.*, 3: 65–76.

HINTON, T., and K. C. ATWOOD. 1940–1. Mottleds in the second chromosome [*Drosophila melanogaster*]. *Carnegie Inst. of Wash. Yearb.*, 40: 231.

HOLLANDER, W. F. 1942. Auto-sexing in the domestic pigeon. *J. Hered.*, 33: 135–140.

——. 1942. A possible case of directed mutation in the pigeon. (Abstract) *Genetics*, 28: 76–77. (1943).

——. 1943. Evidence against directed mutation in pigeons. *Rec. Genet. Soc. Amer.*, 12: 49–50.

——, and L. J. COLE. 1940. Somatic mosaics in the domestic pigeon. *Genetics*, 25: 16–40.

HOLMES, W. F. 1921. The Modena Pigeon. *Bradford, Eng.*: Watmoughs, Ltd.

HORLACHER, W. R. 1930. Studies on inheritance in pigeons VII. Inheritance of red and black color patterns in pigeons. *Genetics*, 15: 312–346.

HUTT, F. B. 1929. A note on Lambert's mosaic in the fowl. *J. Hered.*, 20: 323–324.

——. 1937. Bilateral gynandromorphism in a Barred Rock fowl. (Abstract) *Genetics*, 22: 196.

——. 1937. Gynandromorphism in the fowl. *Poultry Sci.* 16: 354–355. (Abstract)

——, and W. F. LAMOREUX. 1940. Genetics of the fowl. XI. A linkage map for six chromosomes. *J. Hered.*, 31: 231–235.

HUXLEY, J. S., and C. J. BOND. 1934. A case of gynandromorphic plumage in a pheasant re-examined in the light of Lillie's hypothesis of hormone threshold. *J. Genet.*, 29: 51–60.

IMAI, S. 1935. The mechanism of bud variation. *Amer. Nat.*, 69: 587–595.

JAAP, R. G. 1933. Inheritance of white spotting in ducks. *Poultry Sci.*, 12: 233–241.

——, and T. T. MILBY. 1944. Comparative genetics of blue plumage in poultry. *Poultry Sci.*, 23: 3–8.

JOHNSON, W. G., and G. O. BROWN. 1904. The Poultry Book, by many expert American breeders and Harrison Weir. 3 vols. New York: Doubleday, Page, & Co. (See vol. 1, plate facing p. 416).

JONES, D. F. 1937. Somatic segregation in maize and Drosophila resulting in atypical growth. (Abstract) *Genetics* 22: 197.

——. 1937. Somatic segregation and its relation to atypical growth. *Genetics* 22: 484–522.

JUHN, M. 1933. Individual feather succession in the hybrid capon. *Proc. Soc. exp. Biol. N. Y.*, 30: 1264–1266.

KAUFMANN, B. P. 1942. Reversion from roughest to wild type in *Drosophila melanogaster*. *Genetic* 27: 537–549.

KEESLING, H. O. 1924. Yellow-red Carneau. *Amer. Pigeon Jour.* 13: 8.

KNOX, C. W. 1931. Colour chimeras in the domestic fowl. *J. Hered.*, 22: 133–134.

KOZELKA, A. W. 1929. Integumental grafting in the domestic fowl. *J. Hered.*, 20: 2–14.

KUHN, O., and J. KUHN. 1926. Ueber die Scheckung der Haustaube. *Biol. Zbl.*, 46: 440–448.

LAMBERT, W. V. 1929. A half-and-half skin color mosaic in the chicken. *J. Hered.*, 20: 167–169.

LANDAUER, W., and S. D. ABERLE. 1935. Studies on the endocrine glands of frizzle fowl. *Amer. J. Anat.*, 57: 99–134.

——, and L. C. DUNN. 1930. Studies on the plumage of the silver spangled fowl. *Storrs (Conn.) Agric. Coll. Bull.* 163.

LEVI, W. M. 1941. The Pigeon. *Sumter, S. C.*: publ. by auth.

——, and W. F. HOLLANDER. 1939. Structural anomalies and color mosaics observed in a colony of domestic pigeons. *J. Hered.*, 30: 453–457.

LILLIE, F. R. 1931. Bilateral gynandromorphism and lateral hemihypertrophy in birds. *Science*, 74: 387–390.

——. 1942. On the development of feathers. *Biol. Rev.*, 17: 247–266.

——, and HSI WANG. 1941. Physiology of development of the feather. V. Experimental morphogenesis. *Physiol. Zool.*, 14: 103–135.

——, and ——. 1943. Physiology of development of of the feather. VI. The production and analysis of feather chimaerae in fowl. *Physiol. Zool.*, 16: 1–21.

LIPPINCOTT, W. A. 1921. Further data on the inheritance of blue in poultry. *Amer. Nat.*, 55: 289–327.

LYELL, J. C. 1887. Fancy pigeons. (Third ed.) London: L. Upcott Gill.

MACARTHUR, J. W. 1933. Sex-linked genes in the fowl. *Genetics*, 18: 210–220.

MACKLIN, M. T. 1923. A description of material from a gynandromorph fowl. *J. exp. Zool.*, 38: 355–375.

MCCLINTOCK, B. 1938. The production of homozygous deficient tissues with mutant characteristics by means of the aberrant mitotic behavior of ring-shaped chromosomes. *Genetics*, 23: 315–376.

——. 1942. The fusion of broken ends of chromosomes following nuclear fusion. *Proc. Nat. Acad. Sci. Wash.*, 28: 458–463.

METZELAAR, J. 1926. Color breeding in pigeon plumage. *Geneva, Ill.*: Amer. Pigeon Keeper Co.

MILLER, R. A. 1938. Spermatogenesis in a sex-reversed fowl, *Gallus domesticus*. *Anat. Rec.*, 70: 155–189.

MONTALENTI, G. 1934. A physiological analysis of the barred pattern in Plymouth Rock feathers. *J. exp. Zool.*, 69: 269–345.

MORGAN, L. V. 1929. Composites of *Drosophila melanogaster*. *Carnegie Inst. Wash. Publ.* 399, part 8, 224–296.

MORGAN, T. H., and C. B. BRIDGES. 1919. The origin of gynandromorphs. *Carnegie Inst. of Wash.* Publ. 278.

——, J. SCHULTZ, C. B. BRIDGES, and V. CURRY. 1938–9. Investigations on the constitution of the germinal material in relation to heredity. *Carnegie Inst. of Wash. Yearb.*, 38: 273–277.

——, ——, and V. CURRY. 1939–40. Investigations on the constitution of the germinal material in relation to heredity. *Carnegie Inst. of Wash. Yearb.*, 39: 251–255.

——, ——, ——. 1940–41. Investigations on the constitution of the germinal material in relation to heredity. *Carnegie Inst. of Wash. Yearb.*, 40: 282–287.

MULLER, H. J. 1930. Types of visible variation induced by X-rays in Drosophila. *J. Genet.*, 22: 299–334.

MUNRO, S. S. 1938. Induced lateral size asymmetry in the fowl. (Abstract) *Genetics*, 24: 92–93.

——. 1938. A single chromosome explanation of Roberts and Quisenberry's Brahma X Barred Rock mosaic. *J. Hered.*, 29: 389–391.

PAINTER, T. S., and L. J. COLE. 1943. The genetic sex of pigeon-Ring dove hybrids as determined by their sex chromosomes. *J. Morph.*, 72: 411–439.

PATTERSON, J. T. 1929. X-rays and somatic mutations. *J. Hered.*, 20: 260–267.

——. 1932. A new type of mottled-eyed Drosophila due to an unstable translocation. *Genetics*, 17: 38–59.

——. 1933. The mechanism of mosaic formation in Drosophila. *Genetics*, 18: 32–52.

——, and W. S. STONE. 1938. Gynandromorphs in *Drosophila melanogaster*. Univ. Texas Publ. 3825.

PICKARD, J. N. 1929. A brown-and-black rabbit. *J. Hered.*, 20: 483–484.

PUNNETT, R. C., and M. S. PEASE. 1929. Genetic studies in poultry VII. Notes on polydactyly. *J. of Genet.*, 21: 341–366.

QUINN, J. P. 1939. Sexual dimorphism in down and adult plumage of the Pilgrim goose. *J. Hered.*, 30: 55–57.

RAWLES, M. E. 1939. The production of robin pigment in White Leghorn feathers by grafts of embryonic robin tissue. *J. Genet.*, 38: 517–532.

——. 1944. The migration of melanoblasts after hatching into pigment-free skin grafts of the common fowl. *Physiol. Zool*, 17: 167–183.

RHOADES, M. M. 1938. Effect of the D^1 gene on the mutability of the a_1 allele in maize. *Genetics*, 23: 377–397.

——. 1940. Studies of a telocentric chromosome in maize with reference to the stability of its centromere. *Genetics*, 25: 483–513.

RIDDLE, O. 1924. Sex in the right and left sides of the bird's body. *Proc. Amer. Philos. Soc.*, 63: 152–161.

——, and H. H. DUNHAM. 1942. Transformation of males to intersexes by estrogen passed from blood of Ring doves to their ovarian eggs. *Endocrinology*, 30: 959–968.

RIS, H. 1941. An experimental study on the origin of melanophores in birds. *Physiol. Zool.*, 14: 48–69.

ROBERTS, E., and J. H. QUISENBERRY. 1935. A Brahma-Plymouth Rock mosaic. *J. Hered.*, 26: 11–14.

——, and ——. 1935. The Brahma-Plymouth Rock mosaic. *J. Hered.*, 26: 114.

ROBERTSON, W. R. B. 1925. Evidence of somatic segregation of factors for plumage colors in heterozygotes in the turkey. (Abstract) *Anat. Rec.*, 31: 356.

SCHULTZ, J. 1936. Variegation in Drosophila and the inert chromosome regions. *Proc. Nat. Acad. Sci. Wash.*, 22: 27–33.

——. 1939. The function of heterochromatin. *Proc. VII Intern. Genet. Congr. Edinburgh*, 257–262.

SEREBROVSKY, A. S. 1926. "Somatic segregation" in domestic fowl. *J. Genet.*, 16: 33–42.

SHAMEL, A. D., and C. S. POMEROY. 1936. Bud mutations in horticultural crops. *J. Hered.*, 27: 486–494.

SHOWALTER, H. M. 1934. Self flower-color inheritance and mutation in *Mirabilis jalapa* L. *Genetics*, 19: 568–580.

SPRUIJT, C. A. M. 1931. De Structuurduiven. *Gouda:* Koch & Knuttel.

STEELE, D. G. 1926. Studies on inheritance in pigeons XII. Black flecking and its relation to sex. Thesis, University of Wisconsin; part 6.

STEINER, H. 1938. Ueber eine halbseitige "Mutationschimäre" des Wellensittichs, *Melopsittacus undulatus* Shaw. *Rev. Suisse Zool.*, 45: 431–440.

STERN, C. 1935. The behavior of unstable genic loci—an hypothesis. *Proc. Nat. Acad. Sci. Wash.*, 21: 202–208.

——. 1936. Somatic crossing over and segregation in *Drosophila melanogaster*. *Genetics*, 21: 625–730.

STUBBE, H. 1933. Labile Gene. *Bibl. Genetica*, 10: 299–355.

——. 1938. Genmutation. *Hb. Vererbungswiss.*, 2 F 23, 137–171, 185–228.

STURKIE, P. D. 1942. Suppression of a dominant character, polydactylism, in the domestic fowl. (Abstract). *Genetics*, 27: 172.

STURTEVANT, A. H. 1929. The claret mutant type of *Drosophila simulans:* a study of chromosome elimination and of cell lineage. *Z. wiss. Zool.*, 135: 323–355.

——. 1932. The use of mosaics in the study of the developmental effects of genes. *Proc. VI Intern. Congr. Genet. Ithaca*, 1: 304–307.

SUTTON, E. 1940. The structure of salivary gland chromosomes of *Drosophila melanogaster* in exchanges between euchromatin and heterochromatin. *Genetics*, 25: 534–540.

—. 1940. Terminal deficiencies in the X chromosome of *Drosophila melanogaster*. *Genetics*, 25: 628–635.

TAYLOR, L. W. 1932. Inheritance of spangling in the domestic fowl. *J. Genet.*, 26: 385–394.

VECCHI, A. 1936. Un caso di ginandromorfismo bipartito con mosaico somatico nel pollo. *Arch. Zool. Ital.*, 23: 377–395.

WATTERSON, R. L. 1942. The morphogenesis of down feathers with special reference to the developmental history of melanophores. *Physiol. Zool.*, 15: 234–259.

WHITING, P. W. 1928. Mosaicism and mutation in Habrobracon. *Biol. Bull.*, 54: 300–302.

WHITMAN, C. O. 1919. (Posthumous works.) vol. 2. Inheritance, fertility, and the dominance of sex and color in hybrids of wild species of pigeons. (edited by O. Riddle.) *Carnegie Inst. Wash. Publ.* 257.

WILLIER, B. H. 1941. An analysis of feather color pattern produced by grafting melanophores during embryonic development. *Amer. Nat.*, 75: 136–146.

——, and M. E. RAWLES. 1938. Feather characterization as studied in host-graft combinations between chick embryos of different breeds. *Proc. Nat. Acad. Sci. Wash.*, 24: 446–452.

——, and ——. 1940. The control of feather color pattern by melanophores grafted from one embryo to another of a different breed of fowl. *Physiol. Zool.*, 13: 177–201.

——, ——, and E. HADORN. 1937. Skin transplants between embryos of different breeds of fowls. *Proc. Nat. Acad. Sci. Wash.*, 23: 542–546.

WRIEDT, C., and W. CHRISTIE. 1925. Zur Genetik der gesprenkelten Haustaube. *Z. ind. Abst.-Vererb.*, 38: 271–306.

——, and ——. 1929. Vier Verblassungscharaktere bei Tauben. *Z. ind. Abst.- Vererb.*, 50: 292–303.

WRIGHT, L. 1902. The New Book of Poultry. *London:* Cassell & Co. (See frontispiece.)

WRIGHT, S., and O. N. EATON. 1926. Mutational mosaic coat patterns of the guinea pig. *Genetics*, 11: 333–351.

THE BLOOD VESSELS OF THE NERVOUS TISSUE

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THE nervous tissue, more than any other tissue of the body, depends for its normal functioning on the continuous supply of arterial blood. Whenever the volume of blood circulating in the brain is reduced for even a short time unconsciousness results. The nerve cells suffer irreversible damage if the blood flow remains insufficient for too long, the time being measured in minutes. Consequently disturbances in the blood supply of brain tissue and the lesions resulting therefrom constitute a large part of the pathology of the brain. In a tissue whose activity depends so much upon its blood supply, the microanatomical relations between the cells and the blood vessels are of particular interest. Some aspects of these relationships are reviewed here on the basis of recent work in this field.

THE IDENTIFICATION OF ARTERIES AND VEINS BY THEIR MORPHOLOGICAL CHARACTERISTICS

In the brain, as in any other organ, oxygenated blood is carried by arteries which divide into smaller vessels, the finest of which, the capillaries, permit the exchange of oxygen and metabolites between the blood and the tissue. The cerebral capillaries of the placental mammals, including man, are connected with each other in a continuous network which is drained by the veins.

In studying the blood vessels of the nervous tissue the first question to arise is which are the arteries and which are the veins. It is curious that the difference was not known until very recently. Pfeifer in his monographs (1928, 1930) described in the brains of man and cat morphologically different types of blood vessels one of which he designated as arteries, the other as veins. However, as Campbell (1938) pointed out, what Pfeifer thought to be the arteries are actually the veins and vice versa. Unfortunately Campbell's paper came too late to prevent other authors from using in their work Pfeifer's erroneous designation (e.g. Finley, 1936).

A method suitable for the demonstration of the morphological difference between cerebral arteries and veins consists of the injection of the arterial system with a gelatin mass that contains rice starch (Scharrer, 1940c). The rice starch particles fill only the arteries because they cannot pass through the capillaries. When thick sections of brain injected in this way are immersed in an iodine solution, the starch-iodine reaction takes place, and the arteries appear deep black. The veins can be similarly filled in another animal, and the two types of blood vessels can be compared. In such preparations the arteries run in

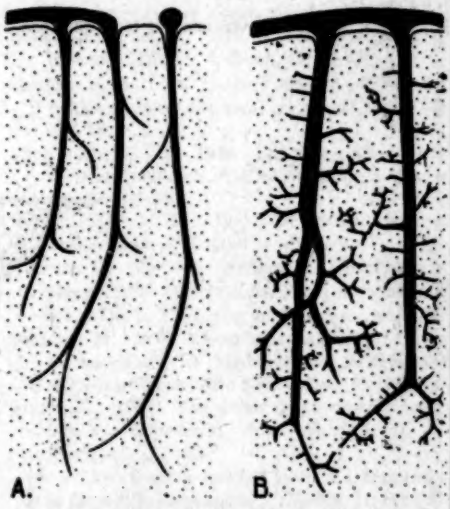

FIG. 1. ARTERIES (A) AND VEINS (B) IN THE CAT'S BRAIN

smooth graceful curves; giving off their branches at acute angles. By contrast the veins receive their tributaries at more obtuse angles (fig. 1). Probably the morphological characteristics of the two types of blood vessels are due to the different conditions of blood flow obtaining in arteries and in veins, but nothing definite is known about that.

THE DISCOVERY OF END-ARTERIES IN THE BRAIN OF THE OPOSSUM

Not in all vertebrates do the arteries and veins of the brain differ in this way. For instance, in

the opossum arteries and veins are alike except that the veins have a larger diameter. The vascular supply of the opossum brain is peculiar also in another respect. Within the opossum brain every artery is accompanied by a vein whose branches are distributed in exactly the same way as those of the artery (fig. 2). The capillaries end in hairpin-like loops which do not anastomose with the capillaries of any neighboring blood vessel (Wislocki and Campbell, 1937; Scharrer, 1938). Only on the surface of the brain, in the pia, arteries as well as veins form networks.

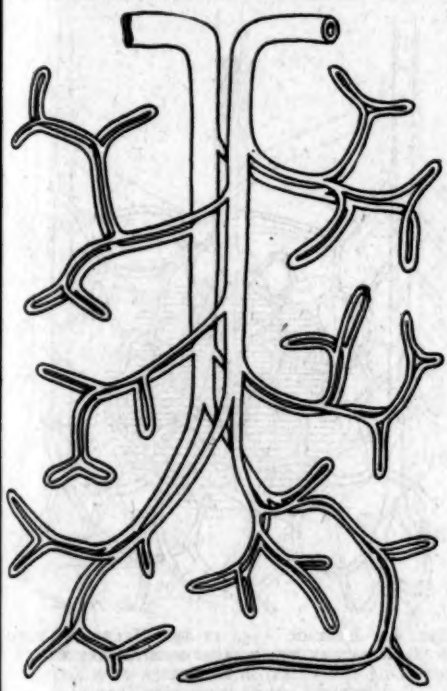

FIG. 2. A UNIT OF ARTERY, VEIN, AND CAPILLARY LOOPS IN THE OPOSSUM'S BRAIN

Theoretically such a unit of artery and vein can be pulled apart (fig. 3). The result is the textbook diagram of an artery, a capillary bed, and a vein. A system of this kind (fig. 3 C) would not be suitable for the supply of nervous tissue because nerve cells surrounding the venous end would be poorly supplied with oxygen. As Craigie (1938b) pointed out, the pairing of arterial and venous limb results in the advantage that the difference between arterial and venous blood becomes equalized throughout the length of the paired vessels.

The capillary loops are not restricted to the opossum, but occur also in the kangaroo (Craigie, 1938b) and in various other Australian marsupials (Sunderland, 1941). Evidently the loops are characteristic of the brains and spinal cords of marsupials in general; other marsupial tissues are not vascularized by capillary loops but by networks. Wislocki and Campbell also called attention to the earlier papers by Schöbl (1878, 1882) and Sterzi (1904) who had described this kind of vascular pattern in certain amphibians and reptiles. The problem of the phylogenetic relationship between the network and the loop arrangement has been studied extensively by Craigie (1938–43), who believes that the loop

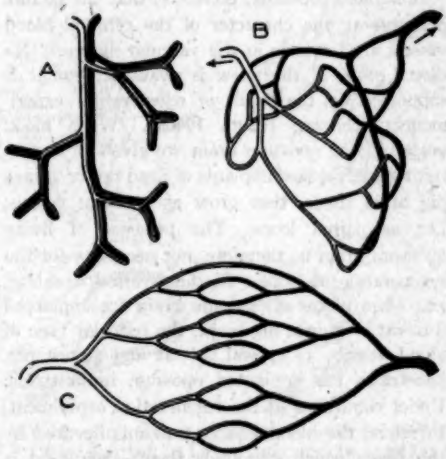

FIG. 3. A VASCULAR UNIT OF THE OPOSSUM'S BRAIN (A) IS PULLED APART IN THE DIRECTION OF THE ARROWS (B) RESULTING IN A SIMPLE PATTERN (C)

system is the more primitive arrangement from which the network type has arisen independently and repeatedly in different groups of vertebrates. But both the two systems, paired blood vessels ending in loops, and single blood vessels forming capillary networks, occur within such primitive groups as the cyclostomes and also in invertebrates. The central nervous system of the earthworm, for instance, is vascularized by loops of the type occurring in the opossum, whereas the central nervous system of the squid possesses a network comparable to that of the placental mammals. It seems rather difficult, therefore, to attribute phylogenetic significance to the two types of cerebral vascular patterns (Scharrer, 1944b, c).

If we look for factors other than the position of

the animal in the phylogenetic order that could determine the type of vascular pattern, the possibility of structural or chemical differences in the brains of animals with networks and those with loops must be considered (Wislocki, 1939). However, it appears unlikely that the nervous tissue of the earthworm, the lamprey, the tailed amphibians, the lizards, and the marsupials has similar structural or chemical properties resulting in the development of capillary loops. On the other hand the brains of the squid, the hagfish, the teleosts, etc., up to and including the placental mammals, would form another group with common structural and chemical characteristics resulting in a reticular network.

It is more probable, therefore, that the factors determining the character of the cerebral blood vessels are intrinsic in the vascular system. No direct proof of this view is available, but it is supported by the result of regeneration experiments (Scharrer, 1939b, 1940a). When blood vessels of the opossum brain are given an opportunity to grow into implants of dead rat or guinea pig brain tissue, they grow as opossum vessels, i.e., as paired loops. The presence of living opossum brain is, therefore, not necessary for the regeneration of loops. In the reversed situation, i.e., when pieces of opossum brain are implanted into rat or guinea pig brain, the reticular type of blood vessels, as typical for rat and guinea pig, penetrates the implanted opossum brain tissue. Under conditions of the regeneration experiment, therefore, the blood vessels grow uninfluenced by the tissue which surrounds them; their type is apparently determined by factors residing in the vascular system.

THE QUESTION OF ANATOMICAL AND FUNCTIONAL END-ARTERIES, AND ITS SIGNIFICANCE IN BRAIN PATHOLOGY, AS ILLUSTRATED BY THE SELECTIVE VULNERABILITY OF THE HIPPOCAMPUS

The discovery of the non-anastomosing capillaries of the opossum has stimulated new interest in an old question, that of the end-artery. In 1872 Cohnheim had postulated that the human brain must be vascularized by end-arteries, i.e., arteries which do not anastomose with each other. The hypothesis of Cohnheim was based on the observation that the occlusion of an artery in the brain by an embolus leads to ischemia and death of the cells in the area supplied by that vessel (fig. 4A). In other organs, where the arteries are connected with each other by anastomoses, the tissue survives such an accident because neighboring arteries can take care of the affected region (fig. 4B). Ever since Cohnheim formulated the concept of the end-artery, it has been interpreted variously, and no clear definition of an end-artery has been given.

In the human brain and in the brains of the common laboratory mammals, end-arteries in the anatomical sense certainly do not exist, since all blood vessels contribute to a continuous capillary network. Evidently end-arteries, in the strict sense of the word, exist only in animals like the

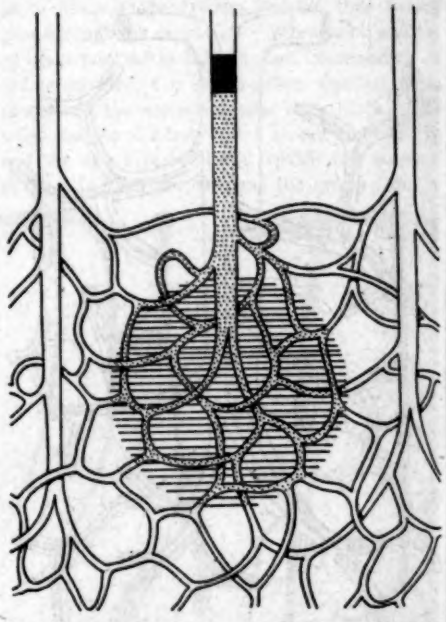

FIG. 4A. ISCHEMIC AREA IN THE NERVOUS TISSUE CAUSED BY THE OCCLUSION OF AN ARTERY BY AN EMBOLUS

opossum, where every artery ends in non-anastomosing capillary loops (fig. 2). Compared with these all arteries whose capillaries anastomose can at best be considered only functional end-arteries. The degree to which they act as if they were true end-arteries will be relative. Their character as end-arteries will depend not only on the number and size of anastomoses present in addition to the capillary connections, but will be also largely a result of the sensitivity of the tissue to ischemia. Capillary connections and small caliber arterial anastomoses, which in other organs might be sufficient to carry the tissue over

the emergency until an effective collateral circulation is established, will not be of much help in the brain. Under conditions of partial ischemia the nerve cells suffer irreparable damage in a very short time, and anastomoses of large diameter would be necessary to supply the afflicted area without delay. Such large anastomoses are lacking between the arteries within the nervous tissue; they are present only on the surface of the brain, where the arteries form a richly anastomosing network. It follows that occlusion of a blood vessel on the surface of the brain should be of much less consequence than that of an artery after it has entered the brain tissue.

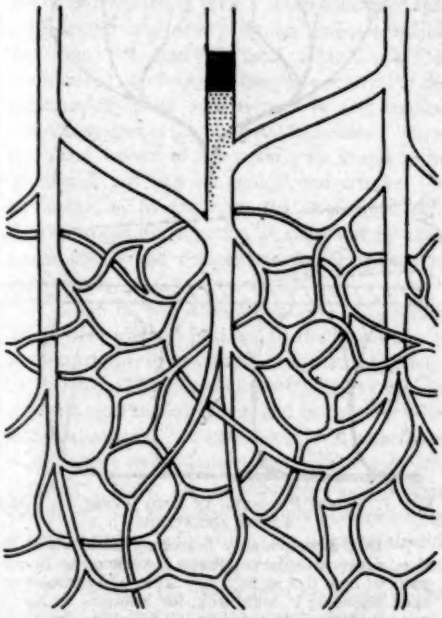

FIG. 4B. THE ROLE OF ANASTOMOSES IN CASE OF OCCLUSION OF AN ARTERY; THE TISSUE IS SUPPLIED BY NEIGHBORING BLOOD VESSELS

It may be said, therefore, that anatomical end-arteries exist in the marsupial brain, but not in the brains of man and all the other placental mammals. The arteries in the latter can be considered only as functional end-arteries, in that anastomotic connections between them are inadequate to provide effective collateral circulation in case one of these arteries becomes occluded by an embolus.

The opossum also proved useful for the study of a number of other questions. One concerns the vulnerability of the hippocampus (cornu ammonis). This is an ancient cortical area, belonging to the olfactory system, which pathologists for a long time have known to be affected selectively in epilepsy. More recently it was found that in many diseases in which the blood circulation is disturbed the nerve cells of the hippocampus may be destroyed (fig. 5) before other parts of the brain suffer (Bodechtel, 1930, 1936; von Braunmühl, 1928; Hiller, 1924, 1936; Hiller and Grinker, 1930; Merritt, 1931; Meyer, 1926, 1928; Neubuerger, 1927; Spielmeyer, 1925, 1927a, 1927b, 1930a, 1930b, 1931; Uchimura, 1928a, Weimann, 1926). The "vulnerability" of the hippocampus was ascribed to peculiarities of its blood supply. It was suggested that the arteries of the hippocampus were even more deficient in anastomotic connections than those of the rest of the brain. Consequently the arteries of the hippocampus would come close to being not only functional but anatomical end-arteries. End-arteries, it was argued, would make the blood supply of the hippocampus so precarious that it could easily fail during an emergency (Uchimura, 1928b).

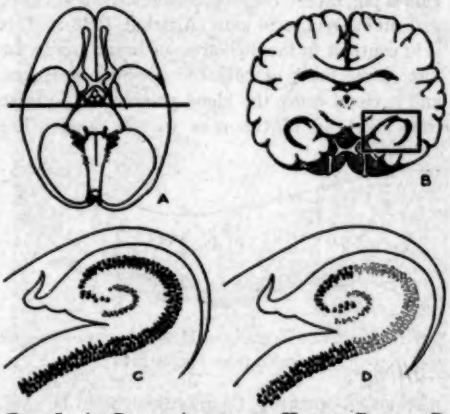

FIG. 5. A. BASAL ASPECT OF HUMAN BRAIN. B. CROSS SECTION AT LEVEL INDICATED IN A BY LINE. THE INCLOSED AREA CONTAINS THE HIPPOCAMPUS. C. NORMAL HIPPOCAMPUS. D. HIPPOCAMPUS WITH LOSS OF CELLS

When the opossum, whose brain is supplied exclusively by true anatomical end-arteries, became available, this explanation of the vulnerability of the hippocampus could be put to a test. Carbon monoxide poisoning, for instance, which in man causes selective lesions in the hippocampus, should result in random damage all over the

opossum brain if end-arterial blood supply renders the brain tissue particularly vulnerable. However, a selective vulnerability corresponding to that observed in man is found in the hippocampus of the opossum in carbon monoxide poisoning (Scharrer, 1940b). Apparently end-arteries as such do not make brain tissue more vulnerable in the case of carbon monoxide poisoning; other factors must play a rôle. They must operate in both man and opossum, capillary network or end-arteries notwithstanding.

The inherent weakness of the vascular system of the hippocampus might lie in the rake-like arrangement (fig. 6) in which the blood vessels come off the main artery in the opossum, rat, guinea pig, rabbit, cat, dog, monkey (Nilges, 1944), and probably also in man (Altschul, 1938). This is in contrast to the dichotomous branching in the rest of the brain of both the opossum and man, and it could cause the blood pressure to decrease from one end of the rake to the other. The

FIG. 6. VASCULAR PATTERN OF HIPPOCAMPUS OF RABBIT
Redrawn from Nilges 1944

mechanism operating there is thought to be similar to that applying to a rubber hose with a series of water outlets, as used in irrigating a lawn. The lower blood pressure at one end of the rake may be assumed to be still ample under normal conditions. However, under the conditions of carbon monoxide poisoning which results in generally low blood pressure and in a great reduction of the oxygen carried by the red cells, the pressure in a part of a rake-like system might be expected to sink beneath the necessary minimum to supply the cells of the hippocampus with sufficient oxygen (fig. 7). The rest of the brain will not suffer quite so soon, although eventually it will. Because in a dichotomous system the decrease in blood pressure is more or less the same in all branches, a critical level will be reached at about the same time in approximately all vessels of the brain and the animal will die. The selective destruction of the hippocampus without damage to the rest of the brain is possible only if the lethal action of carbon monoxide can be brought to bear on the hippocampus before it becomes effective all over the brain. The rake-like pattern of the branches supplying the hippocampus would seem sufficient to account for the difference in time between the destruction of the hippocampus cells and that of the remainder of the brain. At least, if we do not want to resort to hypothetical factors of

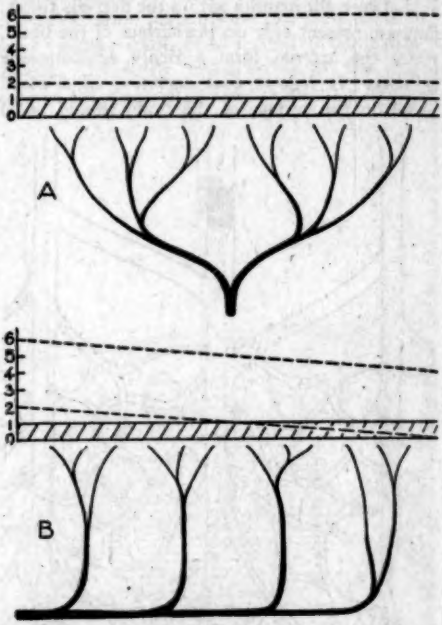

FIG. 7. BLOOD PRESSURE IN TWO TYPES OF BLOOD VESSEL BRANCHING

A. In a dichotomously branching blood vessel the blood pressure in the capillaries is assumed to be normally at level 6 of an arbitrary scale. In carbon monoxide poisoning it could sink, for instance, to level 2 without damage to the cells. The critical level is 1, below which pressure is insufficient to supply the nerve cells with enough oxygen. B. In a rake-like system blood pressure may be expected to decline from one end to the other which is arbitrarily expressed as a drop from level 6 to level 4. The latter is still far above the critical level 1, and under normal conditions the cells are well supplied. In carbon monoxide poisoning the same reduction in blood pressure as that indicated in A will result in too low pressure in part of the tissue, and the nerve cells will suffer damage from insufficient blood supply.

"pathoclisis" (Vogt and Vogt, 1937) and chemico-physical differences between the nerve cells of the hippocampus and those of other parts of the brain, there seems to be only one characteristic in the vascular supply of the hippocampus which man and the opossum have in common, and that is the rake-like branching of the blood vessels. Other-

wise the blood vessels are fundamentally different in the two species, and no other common denominator could be found which would explain the identical selective vulnerability of the hippocampus in man as well as in the opossum.

A METHOD OF DETERMINING THE AREA OF SUPPLY OF A CAPILLARY

The branches and terminal loops of neighboring arteries of the opossum brain interdigitate very extensively. This led Wislocki and Campbell (1937) to suggest that the same area may be supplied by overlapping adjacent units which share the territory between them. They concluded that occlusion of one artery by an embolus might, therefore, not lead to total infarction. This would mean, in effect, the complete reversal of the situation discussed with respect to the cerebral vascular system of the placental mammals. There the blood vessels of the brain were found to be functional, but not anatomical end-arteries. In the opossum, by contrast, the anatomical end-arteries would not function as such, but by their overlapping could compensate for their lack of anastomoses.

In order to test this possibility, lycopodium spores were injected into one of the two common carotid arteries in a number of opossums (Scharrer, 1939a). These animals were killed at various intervals after the injections, and their brains were sectioned serially. In such material it sometimes happens that lycopodium spores occlude only one end-artery, while the neighboring blood vessels remain free. If the areas of supply of neighboring arteries overlap sufficiently, no damage should result from the occlusion of one of them. Actually, however, the nerve cells surrounding the branches of the occluded artery suffer from ischemia, disintegrate, and disappear altogether within 48 hours after the injection of lycopodium spores (fig. 8).

Such lesions permit an estimate of the radius of diffusion of oxygen and nutriments from a capillary into the surrounding nervous tissue. In the granular layer of the cerebellum the width of a strip in which the nerve cells had died following the occlusion of a blood vessel is found to be 50 micra. This is equal to the distance between capillaries in the same area measured in microscopic sections of normal brains whose blood vessels had been injected. Hence a capillary supplies the nervous tissue of the granular layer of the cerebellum for a radius of about 25 micra, or if one capillary is made useless by an embolus in the arterial stem from which it comes, the nerve cells around it die from lack of blood supply for about half the distance between the affected and the neighboring functioning capillary. There is no evidence that their areas of supply overlap. This means a great economy in the vascular bed of the brain since there are evidently sufficient but none too many capillaries to take care of the tissue.

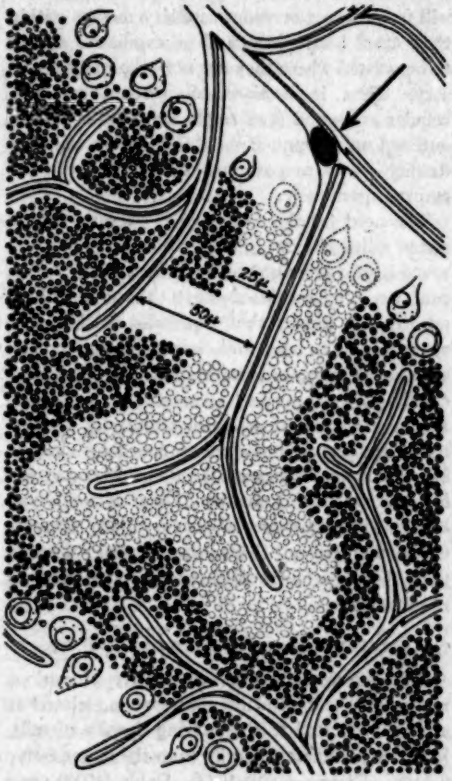

FIG. 8. THE EFFECTS OF OCCLUDING AN ARTERY IN THE CEREBELLUM OF THE OPOSSUM BY A LYCOPODIUM SPORE (ARROW)

The small nerve cells of the granular layer have disappeared in a radius of 25 micra around the capillaries. The cells around neighboring functioning blood vessels are intact.

This principle of greatest possible economy becomes equally obvious if one studies the capillary bed of a part of the brain that contains various types of nervous structures such as groups of crowded large cells, nuclei of loosely arranged

small cells, and fiber bundles. The metabolic requirements of such different areas vary depending upon the presence, density, size, and functional activity of the nerve cells. The various degrees of requirements are most delicately reflected in the density of the capillary bed. Branches of the same artery supplying a region that contains various cell groups and fiber bundles will form denser or wider capillary meshes within their exact borderlines, and no capillaries appear to be wasted where they are not absolutely necessary. Thus in sections of injected material, cellular areas and fiber tracts are often as clearly outlined on account of the differences in capillary density as in preparations where the cells are stained specifically.

The need for this economy of vascular supply seems quite obvious. Within the cranial cavity space is at a premium, and no more blood vessels can be accommodated than those definitely needed. It follows that capillaries in the brain are not likely to open and close as in other organs such as in muscle, because there are no excess capillaries in the brain tissue to be closed off. Furthermore variations in the activity of nervous tissue are probably not accompanied by changes in blood circulation comparable to those occurring in active and resting muscle. The results of physiological investigations (Lennox, 1936; Lennox, Gibbs and Gibbs, 1938) support this view, in that they emphasize the constancy of cerebral blood flow.

THE RELATIONS OF NERVE CELLS TO BLOOD VESSELS

The differences in the vascularity of various regions of the central nervous system, related as already indicated to the varying density of cells, have been studied primarily from the quantitative aspect. Craigie (1920–1933), Cobb (1929), and others reported measurements of the capillary beds in various regions of the brain. In general, it was found that the gray matter of the brain has always a much higher vascularity than the white matter, and that differences exist in the vascularity of different parts of the gray matter.

But there is also a qualitative aspect to be considered. In the diagrammatic figure 9 A blood vessels are indicated as they would appear in a section of injected brain tissue. Their length can be measured and the total length of capillaries per cubic unit of brain tissue can be determined from a number of such measurements. The cellular density of the same area is illustrated in figure 9B. In this way the capillary bed of a given field in the brain can be expressed quantitatively and can be compared with that in other regions. While the data thus obtained permit an adequate estimate of the vascularity of an area in the brain, they are incomplete in certain cases where an additional qualitative factor has to be considered. An example is illustrated in figures 9 C and D. The relationship of the blood vessels of figure 9 A to the cells of figure 9 B can be that

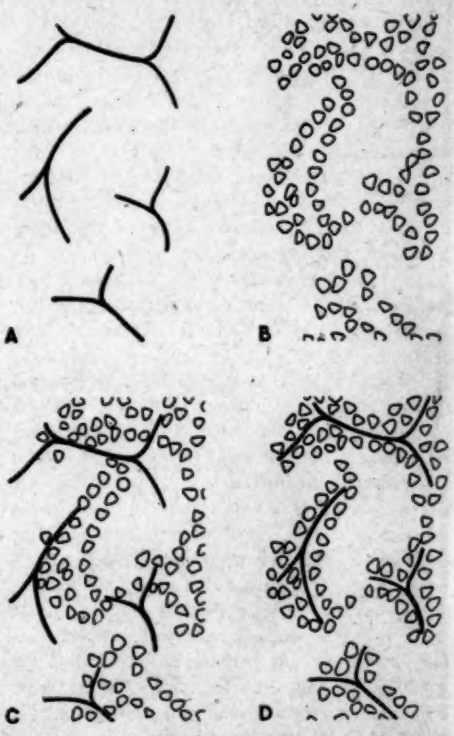

FIG. 9. RELATIONSHIPS OF NERVE CELLS AND BLOOD VESSELS

of either 9 C or 9 D. The cellular and capillary densities are the same in both cases, but the relations of the cells to the blood vessels are obviously different. The cells illustrated in figure 9 D will be better supplied than many cells in figure 9 C, a fact which could not be expressed in a quantitative measurement alone. The perivascular arrangement of the nerve cells illustrated in figure 9 D actually occurs in the optic lobe of the squid (Cajal, 1929).

This leads to an interesting consideration. In

the case of the optic lobe of the squid the cellular pattern is determined by the blood supply. Another example is the nucleus supraopticus accessorius in the mammalian hypothalamus, where the cells also line the blood vessels. As Cajal pointed out, the cellular pattern of the insect brain is determined by the blood supply. The insect brain is surrounded by the blood, but no blood vessels penetrate the nervous tissue to supply the deeper regions. Consequently the cell bodies whose requirements are higher than those of the nerve fibers, are oriented toward the surface.

In other cases the requirements of the nervous tissue determine the vascular architecture, not only quantitatively but also qualitatively. The qualitative aspect applies, for instance, to pericellular capillaries. Very large nerve cells or

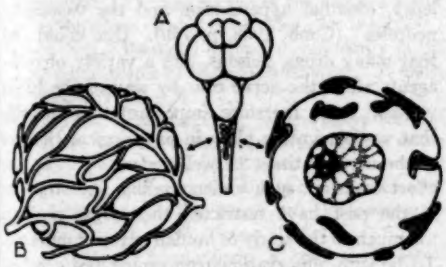

FIG. 10. A. BRAIN OF THE SWELLFISH (*Spheroides maculatus*) WITH EXTRAMEDULLARY NERVE CELLS. B. BASKET OF BLOOD VESSELS AROUND AN EXTRAMEDULLARY NERVE CELL. C. ENDOCELLULAR BLOOD VESSELS AS SEEN IN A SECTION THROUGH THE SAME NERVE CELL

cells which may be assumed to have particularly high metabolic requirements, such as secreting nerve cells (Scharrer and Scharrer, 1940), may be surrounded by capillary baskets. In these cases it would not be enough to determine the capillary length per cubic unit of tissue in order to evaluate the vascularity of the region, but the special relations between the blood vessels and the cells which they supply have to be taken in account.

Pericellular capillaries frequently lie in grooves on the surface of the cell body, and may become embedded in the cytoplasm of the cell when the cell grows around them. In this way capillaries become endocellular, as in the case of the extramedullary nerve cells of the swellfish (*Spheroides maculatus*, fig. 10). Capillaries which are found in the center of the cell may have grown right through it. Such endocellular capillaries have been observed in secreting nerve cells, particularly in fishes, but occasionally may be seen, for instance, in a pyramidal cell of the motor area in the human brain (Scharrer, 1937).

VASCULARIZATION OF THE NEUROPIL

It has been stated above that areas containing densely crowded, large nerve cells possess a particularly rich capillary supply. This is true in general, but there are exceptions which create new problems. An area of large nerve cells, densely placed, but of low vascularity is exemplified by the trigeminal ganglion (Dunning and Wolff, 1937). The discrepancy can be explained if it is assumed that it is not so much the size and density of nerve cells but the number of synapses which determine the vascularity of an area in the brain. Synapses are the terminal structures around nerve cells through which one neuron is in contact with another. It is known that at the synapse chemical processes take place resulting in the liberation of acetylcholine, and that these processes are of significance in the transmission of nervous impulses from neuron to neuron. There are no synapses in the trigeminal ganglion, and its low index of capillary length per cubic unit of tissue would thus be explained.

If this is true one should expect a high vascularity in neuropil. Neuropil is a term applied to areas with few or no nerve cells, consisting of a dense network of nerve fibers and terminal ramifications with many synapses. Olfactory glomeruli are examples of such synaptic fields. Neuropils are often but not always very vascular; some are in fact poorly vascularized, as for instance the molecular layer of the cerebellum.

From this it would appear that the number of synapses is not the decisive factor either. Some types of synapses seem to require more blood supply than others. That this is so is indicated by the observation that the vascularity of various neuropils bears a direct relationship to the number of mitochondria present (Scharrer, 1944a).

The presence of mitochondria at synaptic endings is well known (Held, 1895, 1897; Bartelmez and Hoerr, 1933; Bodian, 1937). These mitochondria are not equally numerous in different neuropils. The neuropil of the nucleus rotundus of the fish brain, for instance, is extremely rich in mitochondria. The same area is about the most densely vascularized region in the whole fish brain. On the other hand, the molecular

layer of the cerebellum is poorly vascularized and shows few mitochrondria.

This correlation, if it can be proved to be general, is not without significance. Lazarow and Barron (1941) have shown that mitochondria are the seat of respiratory enzymes. The presence of mitochrondria in larger or smaller numbers would, therefore, be a measure of respiration at the synapse. Neuropils which contain synapses with many mitochondria and which consequently may be assumed to have a high oxygen consumption are highly vascularized. Others whose synapses are poor in mitochondria and which may be expected to have correspondingly low oxygen requirements are poorly vascularized. At least the observations available at present suggest this correlation; it can be considered a fact only after it will have been tested in a great number of cases.

SUMMARY

1. Some recent work concerning the microanatomical relations between nerve cells and blood vessels is reviewed.

2. Arteries and veins in the brain can be identified by their different types of branching.

3. In all vertebrates so far studied, and in some invertebrates which possess intraganglionic blood vessels, the cerebral vascularization may follow one of two patterns: The capillaries form either a continuous network, as for instance in the placental mammals; or they end in non-anastomosing loops, as in the opossum and in the marsupials in general. In the latter case the brain is vascularized by true end-arteries.

4. The rôle of end-arteries in selective vulnerability of certain parts of the brain, such as the hippocampus, has been studied.

5. The area of supply of single vessels has been demonstrated in the opossum.

6. The arrangement of the blood vessels in the brain is, as a rule, determined by the distribution of the nerve cells. But the latter may be determined in certain cases by the blood vessels, as for instance in the optic lobe of the squid.

7. A marked economy is observed in the vascularization of the brain, in that capillary density varies according to the needs of different localities in the brain.

8. There is evidence that the synapses and their different requirements determine the varying capillary density in the brain.

CONCLUSION

"Many diseases of unknown origin are now thought to be related to disorders of cerebral circulation, foremost among these are migraine, epilepsy, essential hypertension and the vasomotor neuroses" (Cobb, 1938, p. 750). One could add that many drugs, poisons, and a variety of other agents affect the nerve cells by way of the blood vessels. It is, therefore, important that the rôle that vascularization plays in pathological changes of the nervous tissue be well understood. In the effort to attain such understanding, investigators in the past have restricted themselves perhaps too much to the study of human autopsy material. To be sure, observations concerning the cerebral vascular pattern of the earthworm and the opossum help little in clearing up the origin of cerebral vascular lesions in specific clinical cases. However, such observations serve to elucidate certain general principles, an understanding of which is one of the prerequisites for the study of the rôle of vascular factors in the pathology of the nervous system.

LIST OF LITERATURE

In the review articles by Cobb (1932), Gerard (1938), and Wolff (1936, 1938), which have not been referred to in the text, the interested reader will find additional data on the physiology and pathology of cerebral blood vessels.

ALTSCHUL, R. 1938. Die Blutgefässverteilung im Ammonshorn. *Z. ges. Neur. Psychiat.*, 163: 634–642.

BARTELMEZ, G. W., AND N. L. HOERR. 1933. The vestibular club endings in Ameiurus. Further evidence on the morphology of the synapse. *J. comp. Neur.*, 57: 401–428.

BODECHTEL, G. 1930. Die Topik der Ammonshornschädigung. *Z. ges. Neur. Psychiat.*, 123: 485–535.

———. 1936. Zur Bedeutung des vasalen Faktors beim Hirntrauma. *Dtsch. Z. Nervenheilk.*, 140: 286–307.

BODIAN, D. 1937. The structure of the vertebrate synapse. A study of the axon endings on Mauthner's cell and neighboring centers in the goldfish. *J. Comp. Neur.* 68: 117–159.

BRAUNMÜHL, A. VON. 1928. Ueber Gehirnveränderungen bei puerperaler Eklampsie und ihre Entstehung durch Kreislaufstörungen. *Z. ges. Neur. Psychiat.*, 117: 698–727.

CAMPBELL, A. C. P. 1938. The vascular architecture of the cat's brain. A study by vital injection. *Res. Publ. Ass. nerv. ment. Dis.*, 18: 69–93.

COBB, S. 1929. The cerebral circulation. VIII. A quantitative study of the capillaries in the hippocampus. *Arch. Surg.*, 18: 1200–1209.

——. 1931. The cerebral circulation. XIII. The question of "end-arteries" of the brain and the mechanism of infarction. *Arch. Neur. Psychiat.*, 25: 273–280.

——. 1932. The cerebrospinal vessels. In Penfield's *Cytology and Cellular Pathology of the Nervous System*. 2: 577–610.

——. 1938. Cerebral circulation. *Res. Publ. Ass. nerv. ment. Dis.*, 18: 719–752.

COHNHEIM, J. 1872. Untersuchungen über die embolischen Prozesse. *Berlin.*

CRAIGIE, E. H. 1920. On the relative vascularity of various parts of the central nervous system of the albino rat. *J. comp. Neur.*, 31: 429–464.

——. 1921. The vascularity of the cerebral cortex of the albino rat. *J. comp. Neur.*, 33: 193–212.

——. 1925. Postnatal changes in vascularity in the cerebral cortex of the male albino rat. *J. comp. Neur.*, 39: 301–324.

——. 1926. The vascularity of the vagus nuclei and of the adjacent reticular formation in the albino rat. *J. comp. Neur.*, 42: 57–68.

——. 1930. The vascular supply of the archicortex of the rat. I. The albino rat (*Mus norvegicus albinus*). *J. comp. Neur.*, 51: 1–11.

——. 1931a. The vascularity of parts of the spinal cord, brain stem, and cerebellum of the wild Norway rat (*Rattus norvegicus*) in comparison with that in the domesticated albino. *J. comp. Neur.*, 53: 309–318.

——. 1931b. The vascular supply of the archicortex of the rat. II. The albino rat at birth. *J. comp. Neur.*, 52: 353–357.

——. 1931c. The vascular supply of the archicortex of the rat. III. The wild Norway rat (*Mus norvegicus*) in comparison with the albino. *J. comp. Neur.*, 52: 359–364.

——. 1932. The vascular supply of the archicortex of the rat. IV. Inbred albino rats. *J. comp. Neur.*, 55: 443–451.

——. 1933. The vascularity of parts of the cerebellum, brain stem, and spinal cord of inbred albino rats. *J. comp. Neur.*, 58: 507–516.

——. 1938a. The comparative anatomy and embryology of the capillary bed of the central nervous system. *Res. Publ. Ass. nerv. ment. Dis.* 18: 3–28.

——. 1938b. The blood vessels of the brain substance in some amphibians. *Proc. Amer. Philos. Soc.*, 78: 615–649.

——. 1938c. The blood vessels in the central nervous system of the kangaroo. *Science*, 88: 359–360.

——. 1939. Vascularity in the brains of tailed amphibians. I. *Ambystoma tigrinum* (Green). *Proc. Amer. Philos. Soc.*, 81: 21–27.

——. 1940a. Vascularity in the brains of tailed amphibians. II. *Necturus maculosus* Rafinesque. *Proc. Amer. Philos. Soc.*, 82: 395–410.

——. 1940b. The capillary bed of the central nervous system of *Dermophis* (Amphibia, Gymnophiona). *J. Morph.*, 67: 477–487.

——. 1941a. Vascularization in the brains of reptiles. II. The cerebral capillary bed in *Sphenodon punctatum*. *J. Morph.*, 69: 263–277.

——. 1941b. The capillary bed of the central nervous system in a member of a second genus of Gymnophiona—*Siphonops*. *J. Anat. London*, 76: 56–64.

——. 1943. The architecture of the cerebral capillary bed in lungfishes. *J. comp. Neur.*, 79: 19–31.

DUNNING, H. S., and H. G. WOLFF. 1937. The relative vascularity of various parts of the central and peripheral nervous system of the cat and its relation to function. *J. comp. Neur.*, 67: 433–450.

FINLEY, K. H. 1936. Angio-architecture of the substantia nigra and its pathogenic significance. *Arch. Neur. Psychiat.*, 36: 118–127.

GERARD, R. W. 1938. Brain metabolism and circulation. *Res. Publ. Ass. nerv. ment. Dis.*, 18: 316–345.

HELD, H. 1895. Beiträge zur Structur der Nervenzellen und ihrer Fortsätze. *Arch. Anat. Physiol., Anat. Abt.*, Jahrg. 1895: 396–416.

——. 1897. Beiträge zur Structur der Nervenzellen und ihrer Fortsätze. Zweite Abhandlung. *Arch. Anat. Physiol., Anat. Abt.*, Jahrg. 1897: 204–294.

HILLER, F. 1924. Ueber die krankhaften Veränderungen im Zentralnervensystem nach Kohlenoxydvergiftung. *Z. ges. Neur. Psychiat.*, 93: 594–646.

——. 1936. Die Zirkulationsstörungen des Gehirns und Rückenmarks. In *Handbuch der Neurologie* (Bumke-Foerster), *Berlin.* 11: 178–465.

HILLER, F., and R. R. GRINKER. 1930. Functional circulatory disturbances and organic obstruction of the cerebral blood vessels. *Arch. Neur. Psychiat.*, 23: 634–655.

LAZAROW, A., AND E. S. G. BARRON. 1941. The oxygen uptake of mitochondria and other cell fragments. *Anat. Rec.*, 79: 41–42 (suppl. no. 2).

LENNOX, W. G. 1936. Constancy of the cerebral blood flow. *Arch. Neur. Psychiat.*, 36: 375–381.

LENNOX, W. G., F. A. GIBBS, and E. L. GIBBS. 1938. The relationship in man of cerebral activity to blood flow and to blood constituents. *Res. Publ. Ass. nerv. ment. Dis.*, 18: 277–297.

MERRITT, H. H. 1931. Ueber Ammonshornsklerose bei der progressiven Paralyse und ihren Zusammenhang mit den sog. paralytischen Anfällen. *Z. ges. Neur. Psychiat.*, 136: 436–442.

MEYER, A. 1926. Ueber die Wirkung der Kohlenoxydvergiftung auf das Zentralnervensystem. *Z. ges. Neur. Psychiat.*, 100: 201–247.

——. 1928. Experimentelle Erfahrungen über die Kohlenoxydvergiftung des Zentralnervensystems. *Z. ges. Neur. Psychiat.*, 112: 187–212.

NEUBUERGER, K. 1927. Ueber Ammonshornveränderungen bei apoplektischen Hirnblutungen. *Z. ges. Neur. Psychiat.*, 111: 325–331.

NILGES, R. G. 1944. The arteries of the mammalian cornu ammonis. *J. comp. Neur.*, 80: 177–190.

PFEIFER, R. A. 1928. Die Angioarchitektonik der Grosshirnrinde. *Berlin.*

——. 1930. Grundlegende Untersuchungen für die Angioarchitektonik des menschlichen Gehirns. *Berlin.*

RAMÓN Y CAJAL, S. 1929. Signification probable de la morphologie des neurones des invertébrés. *Trab. Lab. Invest. Biol. Madrid*, 26: 131–153.

SCHARRER, E. 1937. Gefäss und Nervenzelle. *Z. ges. Neur. Psychiat.*, 158: 93–99.

——. 1938. Ueber cerebrale Endarterien. *Z. ges. Neur. Psychiat.*, 162: 401–410.

——. 1939a. The functional significance of the capillary bed in the brain of the opossum. *Anat. Rec.*, 75: 319–340.

——. 1939b. The regeneration of end-arteries in the opossum brain. *J. comp. Neur.*, 70: 69–76.

——. 1940a. Further experiments on the regeneration of end-arteries in the brain of the opossum. *J. exp. Zool.*, 85: 365–381.

——. 1940b. Vascularization and vulnerability of the cornu ammonis in the opossum. *Arch. Neur. Psychiat.*, 44: 483–506.

——. 1940c. Arteries and veins in the mammalian brain. *Anat. Rec.*, 78: 173–196.

——. 1944a. The vascularity of neuropil. *Anat. Rec.*, (suppl.) 88: 39.

——. 1944b. A comparison of cerebral vascular patterns in vertebrates and invertebrates. *Anat. Rec.*, (suppl.) 88: 40.

——. 1944c. The capillary bed of the central nervous system of certain invertebrates. *Biol. Bull.* 87: 52–58.

——, and B. SCHARRER. 1940. Secretory cells within the hypothalamus. *Res. Publ. Ass. nerv. ment. Dis.*, 20: 170–194.

SCHÖBL, J. 1878. Ueber eine eigenthümliche Schleifenbildung der Blutgefässe im Gehirn und Rückenmark der Saurier. *Arch. mikr. Anat.*, 15: 60–64.

——. 1882. Ueber die Blutgefässe des cerebrospinalen Nervensystems der Urodelen. *Arch. mikr. Anat.*, 20: 87–92.

SPIELMEYER, W. 1925. Zur Pathogenese örtlich elektiver Gehirnveränderungen. *Z. ges. Neur. Psychiat.*, 99: 756–776.

——. 1927a. Die Bedeutung der Kreislaufstörungen für die Entstehung von Gehirnkrankheiten. *Naturwiss.*, 15: 531–537.

——. 1927b. Die Pathogenese des epileptischen Krampfes. *Z. ges. Neur. Psychiat.*, 109: 501–536.

——. 1930a. Kreislaufstörungen und Psychosen. *Z. ges. Neur. Psychiat.*, 123: 536–573.

——. 1930b. The anatomic substratum of the convulsive state. *Arch. Neur. Psychiat.*, 23: 869–875.

——. 1931. The significance of local factors for electivity in central nervous system disease processes. *Medicine*, 10: 243–256.

STERZI, G. 1904. Die Blutgefässe des Rückenmarks. Untersuchungen über ihre vergleichende Anatomie und Entwickelungsgeschichte. *Anat. Hefte, 1. Abt.*, 24: 1–364.

SUNDERLAND, S. 1941. The vascular pattern in the central nervous system of the monotremes and Australian marsupials. *J. comp. Neur.*, 75: 123–129.

UCHIMURA, J. 1928a. Zur Pathogenese der örtlich elektiven Ammonshornerkrankung. *Z. ges. Neur. Psychiat.*, 114: 567–601.

——. 1928b. Ueber die Gefässversorgung des Ammonshornes. *Z. ges. Neur. Psychiat.*, 112: 1–19.

VOGT, C., and O. VOGT. 1937. Sitz und Wesen der Krankheiten im Lichte der topistischen Hirnforschung und des Variierens der Tiere. *J. Psychol. Neurol.*, 47: 237–457.

WEIMANN, W. 1926. Gehirnveränderungen bei akuter und chronischer Morphiumvergiftung. *Z. ges. Neur. Psychiat.*, 105: 704–751.

WISLOCKI, G. B. 1939. The unusual mode of development of the blood vessels of the opossum's brain. *Anat. Rec.*, 74: 409–427.

WISLOCKI, G. B., and A. C. P. CAMPBELL. 1937. The unusual manner of vascularization of the brain of the opossum (*Didelphys virginiana*). *Anat. Rec.*, 67: 177–191.

WOLFF, H. G. 1936. The cerebral circulation. *Physiol. Rev.*, 16: 545–596.

——. 1938. The cerebral blood vessels—anatomical principles. *Res. Publ. Ass. nerv. ment. Dis.* 18: 29–68.

RECAPITULATION AND ITS SUPPOSED CAUSES

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IN TWO preceding issues of this journal there have been reviews of contributions on the so-called biogenetic law, one by Shumway (1932) and a later one by Meyer (1935). In presenting a further treatment of this topic I have avoided traversing the ground covered by these previous reviews and have confined myself mainly to the discussion of theories of the causes of recapitulation. For this reason the present contribution may be regarded as supplementary to the papers mentioned.

The very existence of a tendency for ontogeny to recapitulate phylogeny has long been a highly controversial question, and one finds distinguished biologists aligned on both sides of it. No one can deny that there is a general resemblance between the ontogeny and phylogeny of higher organisms simply because they start with a simple cell, an ovum or a one celled ancestor, and end in the same adult individual. Oscar Hertwig (1906) has argued at quite needless length that we cannot compare the ovum of a mammal with a unicellular animal because the former differs enormously from the latter in its complex of developmental factors which are the product of a long process of evolution. This obvious difference was recognized by Haeckel and other proponents of the biogenetic law, and I cannot see that it disposes of the recapitulation theory, which must stand or fall on the basis of observations in comparative embryology and morphology. The arguments most relied upon by the recapitulationists are based on similarities between ontogeny and phylogeny which are too specific and peculiar in character to be accounted for as simply a consequence of the increasing complexity of the two series, even though they reach a common goal. This is shown by the embryonic history of the gill arches, renal system, the development of the skull and other skeletal structures, the behavior of rudimentary organs, and numerous other facts adduced by the recapitulationists. Such resemblances are quite generally conceded to be explicable only as a consequence of origin through evolution. But among the biologists who accept this conclusion we find some who contend that facts such as the history of the gill arches in the embryos of birds and mammals are due to a tendency to recapitulate the adult characters of ancestral forms, while others contend that they are merely developmental similarities resulting from a common ancestry. This is the basic issue which has separated controversialists over the biogenetic law from von Baer to the present. There is resemblance, according to von Baer (1828–1837), not between an early mammalian embryo and an adult fish but between a mammalian embryo and a fish embryo up to a certain stage. Von Baer strongly criticized the doctrine of recapitulation as set forth by Kielmeyer (1793), Meckel (1821), Oken (1847), and Serres (1824, 1842, 1859), and substituted for it his own well-known law to the effect that embryos belonging to any of the great groups of animals are at first very much alike and develop along closely similar paths to a degree dependent upon their degrees of affinity. Thus fish, reptiles, birds, and mammals are much alike in their earlier stages, but the fish and mammals diverge first; birds and mammals keep pace longer, and in the mammals man and ape show significant differences only at a relatively later period. Here there is parallelism but not recapitulation.

As set forth by von Baer (1828–1837), this law had no evolutionary implications. It was proposed as a generalization from observed facts of development, whatever might be its causal explanation. Von Baer may have interpreted it in terms of the *Naturphilosophie* by which he was strongly influenced, especially in his early years, partly perhaps owing to his teacher Düllinger who was an adherent of this school. In his post-Darwinian period, von Baer (1864–1876) continued his attack on the doctrine of recapitulation, but since he never committed himself to more

than a guarded and limited advocacy of the genetic derivation of species, he did not accept the evolutionary explanation of his law that came to be so widely adopted by the followers of Darwin.

The pre-Darwinian exponents of the doctrine of recapitulation developed no very plausible explanation as to why recapitulation occurs. The doctrine that ontogeny summarizes phylogeny obviously implies that organisms have a phylogeny. But one who attempts to trace its early history is sometimes perplexed by the uncertainty as to whether or not certain writers regarded the forms of life as constituting a genetically connected series. The phraseology of several authors is very indefinite on this subject and has undoubtedly misled a number of writers who have treated of the history of evolutionary thought, especially Ernst Haeckel and Henry Fairfield Osborn. This phraseology is all the more confusing because of the employment of "evolution" in different senses and because of the reiterated statement that organisms form a closely graded series from the simplest to the most complex and exhibit in their organization a strict conformity to unity of type.

The idea that plants and animals can be arranged in a single series was very prevalent up to the time of Cuvier and Lamarck and was adopted by both creationists and evolutionists, as well as by some who do not appear to fall within either category. It was apparently looked upon favorably by Kant; it fitted very neatly into the speculative set-up of Leibnitz, and it was explicitly defended by Herder, Schelling, Bonnet, and others, but by none of these writers was it given a true evolutionary interpretation. The doctrine that higher organisms in their embryonic development pass through the various stages of the taxonomic series was set forth by creationists, such as Agassiz, and by evolutionists, such as Meckel (1821) and Serres (1824, 1842, 1859), and by some naturalists, such as Oken (1847), who held to the de novo origination of organisms out of primitive *Urschleim* which arose from the purely material elements of sea water under the influence of light. By many naturalists and philosophers the production of organisms de novo was looked upon as a natural and orderly procedure like the growth of a plant from a seed. This attitude was especially characteristic of the participants of that peculiar movement known as *Naturphilosophie* which attained a luxuriant growth in Germany in the closing years of the eighteenth and first few decades of the nineteenth century. Although Kant and Leibnitz must be reckoned among its forerunners, this *Naturphilosophie* was mainly an outgrowth of idealistic philosophy of the period from Fichte to Hegel. Its leading exponent was Schelling, who essayed the task of elaborating a philosophy of nature on the basis of his transcendental idealism. Nature, being the product of reason, was regarded as rigidly orderly and and rational throughout. Schelling (1857, 1858) held that all nature is an organism in which forms show a graded series from matter to man with no gap between the inorganic and organic,—the whole having been produced in accordance with definite laws. Nevertheless, he expressly denied that any one species is ever derived from any other one. Presumably, therefore, they must have arisen de novo by a natural process of spontaneous generation. Perhaps a similar view must be attributed to Hegel (1829), who held that evolution does not occur in nature in any other sense than that of a purely logical development of concepts. Possibly also it must be attributed to Goethe, despite his emphasis on unity of type and his ridicule of the anthropomorphic notions of creation prevailing in his time. It certainly must be attributed to Robinet (1761, 1768), who held that nature succeeded in creating man only after a series of independent spurts, each of which brought her nearer to her goal. And it was also held by Oken, who perhaps represented the vagaries of *Naturphilosophie* at its worst. This is evident from his remarks on the origin of man (1847), in which he tells us that man, like the lower animals "is a child of the warm and shallow parts of the sea in the neighborhood of the land," and that "It is even possible that only one favorable moment was granted in which men could arise. A definite mixture of water, definite heat of blood, and definite influence of light must concur to his production." Oken's speculations on the origin of man appear to have been regarded with favor by Carl Gustav Carus (see his *Grundzüge der vergleichenden Anatomie und Physiologie*, Dresden, 1828). Even the cautious and critical von Baer, who inveighed vigorously against appeals to miraculous creations, vacillated to the end of his days between the origin of distinct types through descent with modification and some form of de novo origination in accordance with natural laws (see his *Reden*, ed. 2., pp. 56, 57, 245, 252, 381–383).

A further treatment of this topic, entitled "Von Baer's Perplexities over Evolution", will appear in *Isis*.

Oken (1847) has stated very definitely that the embryos of higher animals pass through stages represented by adult animals lower in the scale, but he can hardly be called a recapitulationist because he was not an evolutionist. Like others who held similar views, he could not give anything but a mystical interpretation of the parallelism between embryonic stages and the taxonomic series. An earlier formulation of this parallelism had been made by Kielmeyer, who was held in high esteem as a teacher and thinker. A few devoted spirits have represented him as a towering genius ranking among the most eminent scientists of the nineteenth century. In a paper (1793) which is almost his only published utterance he makes the following statement: "Since the distribution of powers in the series of organisms follows the same order as their distribution in the developmental conditions of the same individuals, it can be inferred that the power through which the production of the latter occurs, namely the reproductive power, agrees in its laws with the power through which the series of different organisms of the earth were called into being." In other words, the production of the embryonic and taxonomic series is to be referred to the same causes.

Here we have perhaps the first statement of the doctrine of recapitulation and the first suggestion as to its causes. Kielmeyer treats of development not as a series of structural changes but as a succession of forces or powers. He apparently looks upon the species of organisms as forming a genetically connected series, although his indefinite phraseology is not entirely convincing on this point.

The doctrine of recapitulation was set forth much more explicitly by Meckel (1821) and most copiously by Serres. According to Serres (1842), "The animal series repeats the embryological series and the one is the reproduction of the other in such a way that the embryos exhibit temporarily the characters which the animals possess permanently . . . human organology is a transitory comparative anatomy as in turn comparative anatomy is the fixed and permanent state of the organization of man." According to Serres the appearance of recapitulation is brought about by arresting development at various periods. One might say that there is but one developmental tendency—that of producing man,—and that all inferior creatures are embryos halted on the way. In other words, animals below man represent merely a lot of human abortions occurring at different developmental stages. Both Meckel and Serres adhered to a uniserial classification of animals and were thereby led, like Geoffrey St. Hilaire, into making a number of absurd homologies and also, like Oken, into drawing fanciful conclusions concerning the relations of ontogenetic stages to particular taxonomic groups.

Recapitulation, as expounded by its adherents, was intimately tied up with a lot of ill-grounded speculations that made the devastating criticisms by von Baer an easy task. A number of early writers on embryology were affected by the spirit of the *Naturphilosophie* which led them to seek for comprehensive unifying ideas in their interpretations of nature. The *Naturphilosophie*, despite the extravagancies of a priori speculation which finally brought it into discredit, led its votaries to seek for principles of law and order in natural phenomena and may, therefore, have exercised a stimulating influence upon the development of comparative anatomy. It encouraged the search for homologies and unity of type which were often interpreted idealistically as in the writings of Goethe, Carus, Oken, and Richard Owen. The parallelism between the ontogenic and the taxonomic series was held to manifest some underlying creative principle which in some way not clearly understood is responsible for this relationship.

Up to the middle of the nineteenth century one meets with little except mystical notions on the relationship between embryology and taxonomy. Among those who opposed appeals to miraculous creations, notions concerning the origin of living types were as a rule very vague. Belief in spontaneous generation was quite general, and it was an open question as to how far highly organized types might arise in this way. If rotifers and worms could develop out of non-living material, why not fishes and frogs, or even man? The proponents of the *Naturphilosophie* looked upon the phenomena of nature as directed by forces ranging from those working in a purely mechanical fashion, like gravity, to those manifesting purposive and intelligent guidance. If purpose controls the development of the embryo, as maintained by von Baer and many others, why may it not effect the de novo origination of a highly organized animal as well as an infusorian? The mysterious powers giving rise to the phenomena of life were held to follow definite laws, and if the succession of living forms is guided by purpose, as was generally assumed, the embryonic development of higher types might be expected to show similarities with the successive creative stages

manifested by lower forms. The resemblance of ontogeny to the ascending series of types might thus occur whether the latter were considered as a genetically connected series, as held by Meckel, Serres, and probably Kielmeyer, or as new formations, as held by Schelling, Oken, and other adherents of the *Naturphilosophie*.

I shall call attention to only one other pre-Darwinian writer who has touched upon our theme. This is the much abused author of the *Vestiges of the Natural History of Creation* (1844). Robert Chambers, to whom the authorship of this originally anonymous book is now attributed, was not only violently attacked in theological quarters, but he was at times referred to in slighting if not contemptuous terms by some of the followers of Darwin. "In the reproduction of the higher animals," he tells us, "the new being passes through stages in which it is successively fish-like and reptile-like. But the resemblance is not to the adult fish or the adult reptile, but to the fish and reptile at a certain point in their foetal progress." Chambers had arrived at a more rational conception of recapitulation than had been held by any of his predecessors. How far he may have been influenced by von Baer is uncertain, since he makes no references to this author. He gives several illustrations of the developmental similarities exemplified in von Baer's law, but at the same time he is quite explicit as to the occurrence of recapitulation. His notions of the causes of recapitulation are less satisfactory, but they fit into his general idea of the successive origination of species. "The production of new forms," he states, "has never been anything more than a new stage of progress in gestation." In each stage in the whole advance of life, "we have to trace the effect of an Almighty Will which had arranged the whole in such harmony with external physical circumstances, that both were developed in parallel steps." Progressive evolution is attributed to a developmental power working under divine guidance and producing advanced stages by prolonging gestation when the power operates with greater energy, and leading to monstrosities when reduced in energy. Recapitulation is regarded as a manifestation of developmental arrests, much as it was by Serres. Evolution, according to Chambers, is merely an orderly creation, and phylogeny and ontogeny are more or less alike because the same creative forces operate in both.

In passing from the speculative vagaries of the Romantic Period and from much that is naive and absurd in the *Vestiges* to the discussion of embryology by Darwin in the *Origin of Species*, one becomes translated to a different intellectual world. Darwin was concerned with embryology chiefly as affording support to his doctrine of descent. In the first edition of the *Origin of Species* he makes no reference to von Baer, although he dwells upon the fact that animals commonly resemble one another much more closely in their earlier than in their later stages of development. At this time he may have been unacquainted with the *Entwicklungsgeschichte der Tiere*, since his illustrations of these early resemblances were drawn from fields with which he was very familiar—the larvae of cirripeds, the breeds of pigeons, and the young of domestic animals. In later editions he refers to the evidence adduced by von Baer and quotes one of the latter's questionable statements relating to two early embryos in his possession, concerning which he was "quite unable to say to what class they belonged. They may be lizards, or small birds or very young mammals, so complete is the similarity in the mode of formation of the head and trunk in these animals." Darwin makes effective use of embryological resemblances as indicating genetic relationships, but he goes further and attempts to explain why, in general, although not without exceptions, early embryos are more nearly alike than later ones. The interpretation he offers applies also to recapitulation where this phenomenon appears. His explanation makes a striking advance over those of his predecessors, as we no longer have an appeal to mysterious formative forces but to recognized facts of heredity and the operation of natural selection. This is clearly exemplified in the following passage quoted from the first edition of the *Origin of Species* (1859): "As the embryonic state of each species and group of species partially shows us the structure of its less modified ancient progenitor, we can clearly see why ancient and extinct forms of life should resemble the embryos of their descendants,—our existing species. Agassiz believes this to be a law of nature; but I am bound to confess that I only hope to see the law hereafter proved true. It can be proved true in those cases alone in which the ancient state, now supposed to be represented in many embryos, has not been obliterated either by the successive variations in a long course of modification having supervened at a very early stage, or by the variations having been inherited

at an earlier period than that at which they first appeared. . . .

"Thus, as it seems to me, the leading facts of embryology, which are second to none in importance in natural history, are explained on the principle of slight modifications not appearing in the many descendants from some one ancient progenitor at a very early period in the life of each, though perhaps caused at the earliest, and being inherited at a corresponding not very early period." In the sixth edition of the *Origin of Species* (1872), when discussing how recapitulation may be brought about, Darwin brings out a very important fact in the following passage: "The question is not, at what period of life each variation may have been caused, but at what period the effects are displayed. The cause may have acted, and I believe often has acted, on one or both parents before the act of generation. It deserves notice that it is of no importance to a very young animal, as long as it remains in its mother's womb or in the egg, or as long as it is nourished and protected by its parent, whether most of its characters are acquired a little earlier or later in life. It would not signify, for instance, to a bird which obtains its food by having a much-curved beak whether or not whilst young it possessed a beak of this shape so long as it was fed by its parents."

In discussing the facts and conclusions set forth by Müller, Darwin subscribes to the conclusion that since crustaceans belong to such distinct groups as phyllopods, cirripeds, schizopods, and even some primitive decapods, such as *Penaeus*, pass through a nauplius stage, "it is probable that at some very remote period an independent adult animal, resembling the nauplius, existed, and subsequently produced, along several divergent lines of descent, the above-named great Crustacean groups." But Darwin hastens to explain that recapitulation is not a universal law. "The law will not strictly hold good in those cases in which an ancient form became adapted in its larval state to some special line of life, and transmitted the same larval state to a whole group of descendants; for such larvae will not resemble any still more ancient form in its adult state."

It is clear that Darwin regarded embryonic history as recapitulating in a general way the course of phylogeny. His explanation of the causes of recapitulation involves ideas which have been adopted by two very different groups, the Lamarckians and the neo-Darwinians. Characters acquired through use or disuse might tend to be inherited at earlier and earlier periods and thus give rise to recapitulation, and characters developed through natural selection in the later stages of life might behave in the same way and produce a similar effect. The essential features of the principle of acceleration, concerning which he later had some correspondence with Professor Alpheus Hyatt, had already been set forth in the first edition of the *Origin of Species*, but Darwin explained this only in part as a consequence of the inheritance of acquired characters. It is evident that he regarded it mainly as a result of natural selection in accumulating those variations that became manifest in the later stages of ontogeny.

In most accounts of the doctrine of recapitulation scant justice is given to Darwin's masterly treatment of the subject at a time when virtually nothing but ill-founded speculations on it had been made. In striking contrast to some of his predecessors he did not give free rein to his fancy, but tested the generalizations of von Baer by actual measurements on the young and adults of several species, carefully scrutinized his data for non-conformable facts, and came to conclusions, both as to why recapitulation sometimes occurs and also why it sometimes does not, which have anticipated a number of later hypotheses based on a much greater wealth of knowledge. His treatment makes a great advance over previous discussions of recapitulation in soundness of judgment, grasp of the subject in its varied bearings, and in resourcefulness in devising explanations of the phenomena in terms of heredity and selection.

I need not dwell upon the valuable contributions of Fritz Müller on the evolutionary bearings of development and metamorphosis, but I cannot forbear commenting briefly upon some of the speculations of Haeckel on the causes of his so-called biogenetic law. Haeckel is of course well known as the high priest of this doctrine. For a time the biogenetic law was widely accepted as a matter of course, under a rather vague idea that if evolution occurred recapitulation would somehow follow. Haeckel was very influential in popularizing this conviction. He was a forceful expositor, enthusiastic, endowed with boundless energy, positive, uncritical, dogmatic, intolerant, a hard fighter who wielded a bludgeon, instead of a rapier like Huxley, and he was indefatigable in preaching his gospel through many books and articles in much the same strain for over forty years. With his crude materialistic and so-called

monistic philosophy, he swayed the thinking of thousands of his fellow countrymen. But, although at times he laid himself open to criticisms that did not add to his glory, his scientific activities greatly stimulated the pursuit of knowledge in the fields of comparative embryology and morphology. Looking upon recapitulation as something that necessarily follows from the fact of evolution, Haeckel is naturally led to attempt a causal explanation of this relationship. Recapitulation, he assures us, "is simply a consequence of heredity." "The ontogeny," he says, "as a series of form changes which each individual organism passes through in the entire term of its individual existence is immediately determined through the phylogeny, or the development of the organic phylum to which it belongs." (1866, Bd. 2. p. 300.) This sentence expresses a now old fashioned conception of heredity as the derivation of an organism's characteristics from the corresponding characteristics of its parents, a process which is still implied in theories of Lamarckian inheritance. As might be inferred, Haeckel believed in the transmission of acquired characters, and hence he believed that ontogenies could be molded through accumulating modifications contributed by ancestors, but his attempt at a mechanistic explanation of such transmission, embodied in a paper (1876) bearing the rather pedantic title of "Perigenesis of the Plastidule," is a fanciful production of little scientific value.

Some form of Lamarckian theory, though formerly more than now, has commonly been adopted by the adherents of the biogenetic law whenever they attempted to explain why ontogeny recapitulates phylogeny. The effects of experiences were commonly held to be inherited at the stage in which they were acquired, and since a large part of them occur after development has been completed, they were supposed to crowd previously acquired characters into earlier and earlier periods. This tendency which Hyatt (1889) and Cope (1904) called the Law of Acceleration naturally brings about a repetition of ancestral history in the development of the individual. The hypothesis of acceleration seemed to be supported by the studies of Würtenberger (1880), Waagen (1869), Hyatt (1889, 1893), and later investigators on ammonites, and those of Beecher (1901) on brachiopods, and by other investigators in different groups. It is stated by Cope (1904) that where there is progressive evolution, "characters acquired during the phylogeny are continually assumed by the progressive form at earlier and earlier periods of life." They thus crowd back still earlier characters and may eliminate them entirely. Progressive evolution is thus conceived to occur through successive additions at or near the end of ontogeny, and hence the embryonic development of the organism preserves a modified but more or less faithful record of its phylogeny. This interpretation has been widely adopted by the theorists who would explain recapitulation in Lamarckian terms. Most of these theories, but not all of them, endeavor to construe heredity as analogous to memory. This idea first gained prominence through the well known essay of Hering on *Memory as a General Function of Organic Matter*, published in 1870. In this essay it is contended that there is a fundamental affinity between conscious memory, habit formation, and heredity. All are forms of reproduction. Acts performed once are in general performed more readily and in much the same way on subsequent occasions. Each repetition registers a modification of the organic substance which is at the same time the physical ground of memory, habit and the transmission of acquired characters. This is the gist of the numerous memory theories put forward by Lamarckians. They have been developed in various forms by Erlsberg, Haeckel, His, Samuel Butler (1877, 1880, 1887), Cope (1904), Orr, Pauly, Haacke, Mantia, Semon (1904), Rignano, Francis Darwin, and James Ward. As active formative agents in transmitting the effects of experiences one finds that appeals to vibrations, or wave motions, figure about as prominently in these theories as in writings on occult forces. The memory theories, based as they are upon a very loose and general analogy, are rather baffling to critics because they leave so few opportunities to come to close grips with the problem. When one tries to picture their application in any specific case one is simply lost. It is only when conceived in a vague and nebulous fashion that they have any degree of plausibility. We shall leave them therefore for more tangible subjects.

The earlier pre-Darwinians who accepted the doctrine of recapitulation did so as a rule without making any effort to explain it. Weismann, as might be expected from so consequent a thinker, is one of the exceptions to this rule and he carried on an extensive series of observations on the color markings of caterpillars in the endeavor to obtain evidence bearing on the problem. His find-

ings (1904) led him to conclude that new changes came chiefly toward the end of ontogeny and tend to crowd back the earlier stages. The study is therefore analogous to those carried on with ammonites by Würtenberger (1880), Waagen (1869), and Hyatt (1889, 1893, 1894), and results in similar conclusions as to acceleration, but without assuming Lamarckian inheritance. New characters, he contends, are adaptive and hence due to natural selection, but being based on the old, they tend to push back the old to earlier periods of life. From the Weismannian standpoint it is evident that there is nothing inevitable about recapitulation. Weismann admits this. Nevertheless he holds that there is a tendency for characters to be shunted back, and that "It is certainly not natural selection which effects the shunting back." He concludes that "there must therefore be some mechanical factor in development to which is due the fact that characters acquired in the later stage are gradually transferred to the younger stages (1904, p. 185)." Unfortunately he gives us no clue as to what this mechanical factor may be.

Since a large part of the controversy over the biogenetic law has concerned the question of recapitulation vs. parallelism, any treatment of theories as to the causal factors involved must consider what recapitulation implies. The followers of Haeckel, like his forerunners Meckel and Serres, held that embryonic stages resemble the series of adult ancestors. Haeckel (1866) conceived that this resemblance is less exact than it was held to to be by his predecessors, especially Serres, owing to different degrees of coenogenetic modification. If it were not for these modifications ontogeny, he contended, would be a fairly reliable record of ancestral history, but this record is "falsified" in varying degrees in different types. When recapitulation is interpreted in this sense, its existence is emphatically denied by a large and perhaps increasing number of biologists. Others give the biogenetic law a different interpretation by saying that the stages recapitulated are more embryonic than adult. One might reasonably hold that through the pushing back process structural additions are more or less modified and especially simplified in adaptation to other developmental processes. Whether a structure persists, becomes reduced, eliminated, modified in character, or even increased, doubtless depends in part upon its role in the general physiology of the developing organism. The studies of Oppel (1891), Keibel (1898), Mehnert (1897, 1898), and others have shown that there has been much shifting in the time order of appearance of structures, or heterochrony, in the embryonic development of vertebrate animals,—a fact that led Mehnert and others to conclude that the doctrine of recapitulation should be applied to single organs instead of embryos as wholes.

A structure may be repeated in subsequent embryos in a form approaching its adult condition, if it plays an important role in the formation of other organs, even if its final development should become reduced because it is no longer useful or is even injurious in the mature individual. A study of comparative embryology shows that there is much variation in the tendency of organs lost in the adult to persist in the embryo. Structures recently lost sometimes leave no trace in the development of the embryo, while long-lost organs, such as the notochord in adult mammals, show a remarkable degree of persistence in the development of every individual. The notochord forms a stage in the development of the vertebral column in all higher vertebrates, and this structure, which is more or less similar to its adult condition in primitive chordate types, has not improbably been retained on this account. But it also plays an important role in the differentiation of the nerve cells of the spinal cord through its probably secondarily evolved function as an organizer. For this reason it might possibly have persisted even if the vertebral column had disappeared in the course of evolution.

The retention of gill pouches and gill arches in the embryos of higher vertebrates has long been cited as evidence of recapitulation. The opponents of this doctrine could say that this fact simply shows a parallel development of fish and the higher vertebrates in early stages. The long persistence of these structures, when so many other fish-like characters have disappeared, is commonly explained on the theory that they form necessary stages in the development of permanent organs of the higher vertebrates. The Eustachian tube in man, for instance, arises from an anterior gill slit which is phylogenetically the older organ. It is claimed that if the tube continues to be formed the gill slit must continue to be formed or else some other de novo method must be substituted. This is no easy task, although similar feats have at times been accomplished. By far the easier method is to lug along the old precursory procedures. In many ways an appearance of

recapitulation results from conservatism in the methodology of organ formation.

Although an embryo as a whole would not closely resemble any ancient progenitor, one cannot assert that the same statement necessarily applies to a particular organ. There might be recapitulation of certain ancestral structures or even of a limited succession of them, but even where long lost parts are retained on account of their physiological importance in embryogeny, they usually become greatly modified in course of time. This may be partly owing to the influence of other parts, to changes in the hereditary factors that cooperate in their production, or again to taking on new developmental functions as in the case of several of the endocrine glands. Doubtless the assumption of endocrine activity has saved many an organ from extinction. One might expect, therefore, that the extent to which embryonic organs are palingenetic would be exceedingly varied. By the proper selection of cases one might build up an impressive array of evidences for the theory of recapitulation. This would not prove that ontogeny is largely determined by phylogeny, in the way supposed by Haeckel. Old adult structures may be quickly lost or retained for an apparently unreasonable length of time, depending on circumstances affecting their functional importance in development. There can be no doubt that the critics of the biogenetic law as formulated by Haeckel are right in many of their contentions. Embryos of higher forms do not closely resemble the adult stages of the series of progenitors. But the critics often attempt to dispose of the doctrine of recapitulation too simply, by saying that all the similarities in question are due to the fact that one ontogeny resembles another owing to a common heredity. Garstang (1922), for instance, in an attempt at a critical restatement of the biogenetic law states that "The phyletic succession of adults is the product of successive ontogenies. Ontogeny does not recapitulate phylogeny; it creates it. There is a general correspondence between the successive grades of differentiation in ontogeny and the successive types of organization which characterize the steps of the phyletic progress. This general correspondence exists because each series—the ontogenic and the phylogenic—was preceded by the same phyletic series of ontogenies. The outcome of each successive series was an adult representative of one of the successive types of organization. The last ontogeny of the whole series is the one under consideration. Inevitably there is recapitulation of successive grades of differentiation, but repetition of adult ancestral stages is necessarily and entirely lacking."

If the term ancestral stages is applied to organisms as wholes the last statement is largely true. Let us suppose, however, that a species of insect, B, differs from A in having five more joints in its antennae and that each increase has occurred at a later stage in development than the previous one by a division of the terminal joint. Each ontogenic stage of B would correspond to a phylogenic stage in the transition from A to B. If one considers individual organs it does not follow, therefore, that "the repetition of adult stages is necessarily and entirely lacking." For reasons previously mentioned it may happen that on account of its physiological relations a structure fairly close to its state in an adult ancestor may be retained in the embryological development of its descendants. There is, of course, resemblance between the ontogenies of successive forms, but this does not preclude resemblance in varying degrees of closeness between ontogenic and adult phylogenic structures. Where this occurs one may regard it as a case of recapitulation in the literal sense of this term.

The more recent discussions of the causes of recapitulation have usually been carried on from the neo-Darwinian standpoint. Naef (1917) has put forward what he calls "the law of terminal modification," which he states as follows: "The stages are conservative in proportion as they appear earlier, and progressive in proportion as they appear later in the ontogenetic series." In his Lieferung on *Phylogenie der Tiere*, Naef (1931) lays down the following principle: "Morphogenetic processes of an ontogenetic stage through whose modification a following stage arises are to be looked upon as phylogenetically older than those which grew out of them." Prolongation of the development with additions at late stages would give rise to recapitulation, whereas a shortening of the process would effect the loss of end stages and simplification of structure.

The tendency to develop additional structures at or near the end of ontogeny has been especially emphasized by Sewertzoff (1931), who has adduced much factual evidence in support of his conclusions. He recognized, however, as in fact others have done, that evolution does not always take place by additions in the later stages of the embryonic series. He distinguishes three types of

ntogenic change, according as they occur at the eginning, middle, or terminal period of develop- ent. These three modes Sewertzoff attempts to how are correlated with different types of phylo- eny. Where additions are made to the end tages leading to a progressive modification, the inal stage of the ancestral forms is retained and hus repeated in the Haeckelian sense. The erminal stages, Sewertzoff holds, are modified lowly by accumulating small variations. Where hanges occur in the middle period there may be ecapitulation up to that point also, but when they ccur near the beginning there is no recapitulation, nd the change is likely to produce an abrupt and xtensive modification. Sewertzoff concludes that "The law of recapitulation and von Baer's law are not universally valid; they are entirely valid only for organs which have developed by means of additions to end stages" (p. 366). I am not able to do justice to the contributions which the researches of Sewertzoff have made to our problems. They constitute the most significant factual additions to our knowledge in this field in recent decades. They show that the relations of ontogeny and phylogeny cannot be expressed in terms of one general principle. The relationships involved are contingent, however widespread may be their occurrence.

The writers thus far considered have viewed the problem of recapitulation chiefly from the standpoint of comparative anatomy, embryology, and paleontology. The reasons for recapitulation or parallelism were sought first of all in the conservatism of heredity, terminal acquisition, and the pushing back of characters in ontogeny; and modifications were attributed to retardation, heterochrony, suppression, and the appearance of variations at different periods. In a few recent contributions the problem has been treated from the standpoint of modern genetics. A geneticist naturally looks upon phylogeny as a succession of ontogenies which owe their hereditary differences to variations in the genes with which they start. The stream of germ plasm gives rise to both ontogeny and phylogeny and to whatever relationships may subsist between them. All evolution in organisms is simply the manifestation of the one basic evolution of the *Keimbahn*, or continuous germ plasm. The developmental factors carried by the germ plasm affect ontogeny at different stages. Some genes may lie latent because conditions necessary for their activity are not furnished until a certain stage is reached. If we regard genes as catalytic agents, the conditions for their manifestation may be supplied by certain substances produced by other genes. A regular sequence of morphogenetic gene activities may be determined in this way.

In his latest book, *The Material Basis of Evolution*, Goldschmidt (1940) has applied his theory of gene action developed in his *Physiologische Theorie der Vererbung* (1927) to the interpretation of recapitulation as follows: "If macroevolutionary changes proceed by mutations affecting the rate of embryogenetic processes at a definite time in development, the ontogeny of all descendants of the mutant form must continue along ancestral lines up to the stage in development first affected by the mutant. . . . The presence of recapitulation shows positively that the original mutational change in the ancestors affected development after the stage which is recapitulated." (p. 389) The influence of gene mutation in the course of development would therefore depend largely on when the mutant genes begin to function. Early activity, by modifying subsequent changes, would tend to obliterate the ancestral record. Hence recapitulation would be evident in proportion as gene mutations become active toward the end of ontogeny. One is naturally led to ask, therefore, whether mutations are unusually prone to appear at this time, and if so, why. One very simple reason for their late manifestation is because such changes are not easily recognized in early periods. A germinal change affecting a blastula or gastrula is very likely to be overlooked. A mutant gene that would give rise to a club foot, for instance, would probably not produce a noticeable effect before the fomation of limb buds even if it were active very early. As embryos grow more complex, the chances for a mutant gene to produce a *recognisable* effect would be greatly multiplied. Hence a certain tendency of new characters to *appear* in the later stages of development is thus merely a statistical consequence of increasing complexity.

But aside from this simple circumstance, which affects appearances only, there is the fact that with increasing differentiation, there are more opportunities for slumbering genes to find conditions suitable for their activities. Many genes are forced to lie dormant because no material is yet available upon which they can act. Late embryos present a remarkable amount of chemical differentiation in their several regions. In higher organisms there are many different kind of genes,

and one furnishes the soil in which another can operate. Moreover, gene mutations have to fit into the ontogeny without too greatly disrupting its course. If they manifest themselves toward the end of it, when there are few or no further processes to be thrown out of gear, they would not be so likely to be eliminated by natural selection. Both Goldschmidt and Sewertzoff have contended that gene mutations that act early are likely to produce extensive changes in ontogeny. In 1913 Wilhelm Roux had expressed a similar idea, in that "for the most part only such new variations of the germ plasm accumulate in phylogeny which first are developed toward the end of ontogeny." Our present knowledge of lethal mutations clearly indicates that the fatality of gene expression in very early development is exceedingly high. How much of this mortality is attributable to the nature of the mutations and how much to the period in which they act we do not know. A priori, it seems probable that the earlier the change, and therefore the greater the subsequent modifications entailed, the less likely it would prove to be advantageous. Early stages would seem therefore to be especially guarded against change. They do change, but the directions of adaptive modifications are relatively limited, if they do not prove injurious to the subsequent ontogeny.

Another cause of the appearance of recapitulation is found in the relation of bodily size to the relative growth of parts. In many organisms it has been found that the ratio of the growth of parts to the growth of the whole remains fairly constant for a considerable time. As some organs grow more rapidly than others, the different growth ratios lead to definite changes of form. Much of the data on this subject has been amassed by Julian Huxley in his *Problems in Relative Growth* (1932). The horns of deer grow relatively faster than other parts, and develop more prongs with increasing age. Paleontological data show a parallel evolution from older and smaller species to larger recent types with relatively larger and more branched antlers. This parallel between the ontogenic and the probable phylogenic development of horns in deer has often been cited in the books as an illustration of recapitulation. In one sense it is, but the causes of it probably lie in the physiological and genetic factors that lead to differential rates of growth and development. These rates may be expressed in a mathematical formula $y = bx^k$ where y = volume of part, x = volume of whole, and b and k are constants. This formula has been found in many investigations to fit quite closely the measurements taken at different stages. Constant differential growth rates often lead to excessive developments as size increases, and furnish many of the evidences adduced in favor of orthogenesis. An interesting case is furnished by the evolution of the extinct titanotheres, in which Osborn (1929) has shown that there has been a parallel evolution of horns from mere stubs to large horns in four independent lines. Hersh (1934) has investigated these types and finds that the relative growth rates of the horns conform to the formula mentioned, with the same constants b and k for each series, but that these constants differ from one series to another. Thus the alleged orthogenesis of these forms is probably an expression of different developmental rates which go along with increase of size.

There are, therefore, several reasons for the accumulation of gene manifestations in late ontogeny and hence the appearance of recapitulation. Nevertheless, the doctrine of recapitulation cannot lay claim to being a law. Nor does it express a nearly universal tendency. What is acquired late in phylogeny may appear early in ontogeny, as is shown by the early manifestations of many new mutations, and what is acquired early in phylogeny, like metamerism in the mammalian embryo, may arise later than the folds of the amnion which are phylogenetically a much more recent development. The particular relations of ontogeny and phylogeny are subject to extensive changes. The several causes that bring about an appearance of recapitulation are quite different in their nature and different again from those that effect the direction of evolution.

A number of critics have pointed out that the Haeckelian distinction between palingenic and coenogenic characters is not valid. Both depend upon germinal mutations, presumably accumulated on account of their adaptive value. A coenogenic character in a larval or embryonic stage is just as indicative of a similar character in ancestry as is any character of the adult. Each stage has its phylogeny, in relation to which its hereditary characters may be palingenic.

Another objection to the theory of recapitulation that deserves more attention is the claim that phylogeny cannot in any sense be the cause of ontogeny, as was claimed by Haeckel. Modifications of ontogeny, it is asserted, cause phylogeny, and not the reverse. But the term phylogeny was originally applied to a genetically

connected series of adult stages. It is a historical series, and the only genesis involved in it is through the ontogenies by which it is created. DeBeer in the concluding chapter of his valuable analysis of recapitulation theories in *Embryos and Ancestors* (1940), tells us flatly that "phylogeny plays no causal part in determining ontogeny," and that it "does not explain ontogeny at all." The experimental embryologist, as DeBeer conceives him, is supposed to deal with factors such as organizers, etc., which are the immediate causes of the phenomena upon which he experiments. If the experimental embryologist should ever accomplish the stupendously difficult task of giving a causal explanation of the course of any ontogeny, his achievement would be analogous to explaining on mechanistic principles how the time keeping of a watch results from its structural configuration. As the Reverend Mr. Paley would doubtless insist, it is the preformed structure of the watch which most requires explanation, and for this problem one is compelled to have recourse to a teleological interpretation. Suppose we succeed in tracing the chain of ontogenic causes back to the complex of genes with which development begins, and find that this complex, like the structure of the watch, determines the course of events that follows; we would then have arrived at one stage which is as much the product of antecedent causes as any stage that comes after it. A causal explanation of development that accounts for its teleological aspects would include a knowledge of the steps by which the germ plasm came to be so constituted that it develops into a harmoniously functioning whole. If we follow these steps back and back, we should find that the germ plasm was constituted thus and so, because certain ancestors survived in the struggle for existence. To a limited extent man determines the kind of ontogenies that are followed in his domesticated animals and plants through selecting the individuals he permits to breed. And since nature does much the same sort of thing, one may look upon ontogeny as being in a sense guided by its phylogenic history.

Back of every ontogeny is a long history of ever-branching and interlacing strands of germ plasm that is carried by the bodies which spring up at the meeting points of the strands. The complete ontogenies of all living organisms that arise from the nodes of the network of germ plasm are equally old; their apparent age differences concern only the small parts of their lives spent in one body instead of as separate strands carried by innumerable progenitors. If I were able to explain why I am constructed as I am, instead of being an angle-worm or a black widow spider, I should have to know much about the multitudes of ancestors that carried the strands of germ plasm which have converged to produce my present outfit of genes. In other words, I should have to go into the subject of phylogeny quite extensively, if I were ever to gain an adequate causal explanation of my own ontogeny.

DeBeer concedes that modifications due to external factors might affect ontogeny if acquired characters are inherited. But since this is regarded as a very doubtful hypothesis, "it cannot be stated that phylogeny plays any part in ontogeny at all." If, however, external factors influence the kinds of variations that survive, as they demonstrably do, and if these variations influence the kinds of ontogenies that occur in the offspring, I cannot see, so far as our problem is concerned, that it makes any difference whether these conditions operate through the transmission of acquired characters, or by means of natural selection. In either case the events that form a part of the phylogenic history play a role in shaping the course of ontogeny. In fact, this conclusion is inevitable if we accord to phylogeny any sort of status as a real series of events.

We cannot regard phylogeny as a mere passive *Ahnenreihe* like a series of ancestral portraits. Phylogenic history is as much a record of actual happenings as the events of human history, some of which are of chief interest to the biographer and others to the student of mass movements. It is of course obvious that phylogeny is made up of individual ontogenies and would have no existence without them, but it is also obvious that the complete history of the race would include all the events occurring in the development of every individual. After all, we are dealing with the same facts from different points of view. The occurrences which for the purposes of scientific interpretation it is useful to consider as belonging to phylogenic history may cause and be caused by other events which we commonly regard as belonging to ontogenic development.

The particular ontogeny of John Smith may have been what it was because Mrs. Green decided to give the party at which Henry Smith met Hannah Jones. This meeting may be construed as an episode of phylogenic history or as an event in the

ontogeny of the individuals concerned. But we must not forget Mrs. Green, without whose well-intentioned matchmaking proclivities a particular ovum might have developed into a quite different kind of a person from John Smith. The events of phylogenic history may affect successive generations not only through direct inheritance but in various other ways. The incidence of selection, for instance, may have different effects upon ontogenies in different environments. Whether or not the ontogenies are modified so as to produce the appearance of recapitulation, however, would depend upon many circumstances.

Our brief survey has shown, I think, that the doctrine of recapitulation has had a rather curious history. This is largely because recapitulation has turned out to be something quite different from what it seemed to most of its adherents. We cannot regard it as a uniform expression of the mysterious creative forces of nature, as held by Kielmeyer, nor as a direct consequence of heredity, as maintained by Haeckel. We cannot consider it a manifestation of memory like the repetition of a tune, nor as a mechanically determined pushing back of embryonic characters, as postulated by Weismann. We may be justified in construing it as in part a function of the way in which germinal mutations fit into the physiology of development, but the appearance of recapitulation may also be merely an expression of the uniformities of relative growth. In the light of present knowledge, recapitulation represents no simple principle deducible from some more general law. It is rather a conglomerate effect of heterogeneous causes. We shall doubtless know more of at least some of these causes when the causal factors of embryonic development are better understood than they are today.

LIST OF LITERATURE

AMEGHINO, F. 1937. Filogenia. *Buenos Aires.*

BAER, K. E. VON. 1828–1837. Ueber Entwicklungsgeschichte der Thiere, Beobachtung und Reflexion. *St. Petersburg.*

——. 1864–1876. Reden. *St. Petersburg.*

BALSS, H. 1930. Kielmeyer als Biologe. *Arch. Gesch. Med.*, 23: 268–288.

BEECHER, C. E. 1901. Studies in Evolution. *New York.*

BEER, G. R. DE. 1940. Embryos and Ancestors. *Oxford.*

BUTLER, S. 1877. Life and Habit. *London.* ed 3, 1911.

——. 1880. Unconscious Memory. *London.*

——. 1887. Luck or Cunning. *London.*

CARUS, C. G. 1828. Grundzüge der vergleichenden Anatomie und Physiologie. *Leipzig.*

CHAMBERS, R. 1844. Vestiges of the Natural History of Creation. *London.*

COPE, E. D. 1904. The Primary Factors of Organic Evolution. *Chicago.*

DARWIN, C. 1859. The Origin of Species by Means of Natural Selection. *London.* (6th ed., 1872.)

FRANZ, V. 1927. Ontogenie und Phylogenie, in *Abhandlungen zur Theorie der organischen Entwicklung* H. 3.

GARSTANG, W. 1922. The Theory of Recapitulation. A Critical Restatement of the Biogenetic Law. *London.* J. Linn. Soc., 35: 81–101.

GOLDSCHMIDT, R. 1927. Physiologische Theorie der Vererbung. *Berlin.*

——. 1940. The Material Basis of Evolution. *New York.*

HAECKEL, E. 1866. Generelle Morphologie der Organismen. *Berlin.*

——. 1876. Die Perigenesis der Plastidule. *Berlin.*

HALDANE, J. B. S. 1932. The Causes of Evolution. *London and New York.*

——. 1932. The Time Action of Genes. *Amer. Nat.*, 66: 5–24.

HEGEL, G. W. F. 1929. System der Philosophie. Th. 2, Die Naturphilosophie. Sämmtliche Werke, Bd. 9, Jubiläumsausgabe. *Stuttgart.*

HERING, E. 1870. Memory as a General Function of Organic Matter. *Trans. Chicago*, 1895.

HERSH, A. H. 1934. Evolutionary Relative Growth in the Titanotheres. *Amer. Nat.*, 68, 537–561.

HERTWIG, O. 1912. Allgemeine Biologie, 6th and 7th ed., *Jena.*

——. 1906. Handbuch der vergl. und exper. Entwickl. der Wirbeltiere, III, Th. 3, 149–183.

HURST, C. H. 1893. The Recapitulation Theory. *Nat. Sci.*, 2: 195–200.

HUXLEY, J. S. 1932. Problems in Relative Growth. *New York.*

HYATT, A. 1889. The Genesis of the Arietidae. *Mem. Mus. Comp. Zool. Harvard*, 16, No. 3.

——. 1893. Phylogeny of an Acquired Characteristic. *Amer. Nat.*, 27, 865–877.

——. 1894. Ibid. *Proc. Amer. Philos. Soc.*, 32: 349–647.

KEIBEL, F. 1898. Das biogenetische Grundgesetz und die Coenogenese. *Ergeb. Anat. EntwGesch.*, 7: 722–792.

KIELMEYER, L. F. 1793. Ueber die Verhältnisse der Organischen Kräfte unter einander in der Reihe

der verschiedenen Organisationen, die Gesetze und Folgen dieser Verhältnisse. Reprinted in *Sudhoff's Arch. Gesch. Med.*, 23: 247–267, 1930.

KRYZANOWSKY, S. G. 1939. Das Recapitulationsprinzip. *Acta Zool.*, 20: 1–87.

LILLIE, F. R. 1908. The Development of the Chick. *New York.*

MACBRIDE, E. W. 1917. Recapitulation as a Proof of the Inheritance of Acquired Characters. *Scientia*, 22: 425–434.

MECKEL, J. F. 1821. System der vergleichenden Anatomie.

MEHNERT, E. 1897. Kainogenese, *Morph. Arb.*, 7: 1–156.

——. 1898. Biomechanik. *Jena.*

MEYER, A. W. 1935. Some Historical Aspects of the Recapitulation Idea. *Quart. Rev. Biol.*, 10: 379–396.

MONTGOMERY, T. H. 1906. Analysis of Racial Descent in Animals. *New York.*

MORGAN, T. H. 1903. Evolution and Adaptation. *New York.*

——. 1924. Heredity of Embryonic Characters. *Scient. Mon.*, 18: 5–17.

NAEF, A. 1917. Die individuelle Entwicklung organischen Formen als Urkunde ihrer Stammesgeschichte. *Jena.*

——. 1919. Idealistische Morphologie und Phylogenetik. *Jena.*

——. 1931. Phylogenie der Tiere, *Hb. Vererbungswiss.*, Bd. 3.

NAUCK, E. T. 1931. Ueber umwegige Entwicklung. *Morph. Jahrb.*, 66: 65–195.

NEEDHAM, J. 1930. The Biochemical Aspect of the Recapitulation Theory. *Biol. Rev.*, 5: 142–158.

——. 1931. Chemical Embryology. *Cambridge and New York.* (Vol. 3, 1632 ff.)

——. 1942. Biochemistry and Morphogenesis. *Cambridge.*

OKEN, L. 1847. Elements of Physiophilosophy. (Translated by Tulk). *London.*

OPPEL, A. 1891. Vergleichung des Entwicklungsgrades der Organe zu verschiedenen Entwicklungszeiten bei Wirbeltieren. *Jena.*

OSBORN, H. F. 1929. The Titanotheres of Ancient Wyoming, Dakota, and Nebraska. U. S. Dept. Int., Geol. Surv. Monogr. 55.

PERRIER, E. and GRAVIER, C. 1902. La tachygenèse ou accélération embryogénique. *Ann. Sci. Nat. Zool.*, (8), 16: 133–371.

ROBINET, J. B. R. 1761–1766. De la Nature, 4 vols. *Amsterdam.*

——. 1768. Considérations Philosophiques sur la gradation naturelle des formes de l' être. *Paris.*

ROUX, W. 1913. Ueber die bei der Vererbung von Variationen anzunehmenden Vorgänge. *Roux's Vorträge und Aufsätze über EntwMech.*, 19: 1–68.

RUSSELL, E. S. 1916. Form and Function. *London.*

——. 1930. The Interpretation of Development and Heredity. *Oxford.*

SCHELLING, F. W. J. 1857–1858. Sämmtliche Werke. Bd. 2 and 3. *Stuttgart and Augsburg.*

SCHINDEWOLF, O. H. 1936. Palaeontologie, Entwicklungslehre und Genetik. *Berlin.*

SCHMIDT, H. 1909. Das biogenetische Grundgesetz Ernst Haeckels und seine Gegner. 2d ed. *Frankfurt.*

SEMON, R. 1904. Die Mneme. *Leipzig.* 3d ed., translated 1921.

SERRES, E. R. A. 1824. L'anatomie comparée du cerveau dans les quatre classes des vertébrés. *Paris.*

——. 1842. Précis d'anatomie transcendante appliquée a la physiologie. *Paris.*

——. 1859. Principes d'embryogénie, de zoogénie et de tératogénie. *Paris.*

SEWERTZOFF, A. N. 1931. Morphologische Gesetzmässigkeiten der Evolution. *Jena.*

SHUMWAY, W. 1932. The Recapitulation Theory. *Quart. Rev. Biol.*, 7: 93–99.

VIALLETON, L. 1908. Un problème de l'évolution; la théorie de la récapitulation.

WAAGEN, W. W. 1869. Die Formenreihe des Ammonites subradiatus. *Geognostisch-palaeontologische Beiträge v. Benecke*, 2: 179–257.

WEISMANN, A. 1904. The Evolution Theory. 2 vols. *London.*

WÜRTENBERGER, L. 1880. Studien über die Stammesgeschichte der Ammoniten. *Leipzig.*

NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to B. H. Willier, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *Department of Biology, Homewood Campus, The Johns Hopkins University, Baltimore 18, Maryland, U. S. A.*

THE INORGANIC NUTRITION OF PLANTS

A review of *Lectures on the Inorganic Nutrition of plants*, by D. R. Hoagland. *Massachusetts* (The Chronica Botanica Company); *New York* (G. E. Stechert and Company). $4.00. 9 x 6; 226. 1944.

By Folke Skoog, Department of Biology, The Johns Hopkins University.

This book, the most recent addition to the Chronica Botanica "New Series of Plant Science Books" edited by Frans Verdoorn, is based on a series of seven lectures given under the Prather Lectureship at Harvard University in 1942. It is intended, first of all, as a general summary and review integrating the significant achievements along several lines of investigation pertaining to plant nutrition that have been conducted by the author and his collaborators in the Division of Plant Nutrition at the University of California during the past two decades.

As is well known, the work by these investigators has yielded decisive results providing the principal bases for much of our present knowledge concerning processes of salt absorption, salt accumulation, and the translocation of inorganic nutrients in plants. Their extensive quantitative work on mineral requirements and the essentiality of "micro-nutrient elements" has yielded even more spectacular results, if not from a scientific at least from a practical or popular standpoint. If the book contained nothing but a compilation of these results and discoveries, it would be of sufficient interest to be received enthusiastically by plant physiologists. It has, however, a much wider scope. The author has aimed at a presentation of the subject of plant nutrition as a whole, although by no means independent, field of biological science. He has collected the most significant findings from the several different lines of investigation that he has pursued, covering the range from physical chemistry of soil colloids and tissue metabolism to practical agriculture, and he has wrought from this wide experience as complete an exposition and general interpretation of the complex "soil-plant-atmosphere system" as may be attained at the present time. With this purpose in view, each lecture or chapter presents illustrative experimental data on a specific topic, as indicated, for example, by the titles for the 2nd, 3rd, and 4th lectures, which are respectively: "Micronutrient elements and plant growth"; "Absorption and accumulation of salts"; and "Upward movement and distribution of inorganic solutes in plants." The data supplied for each topic are critically analysed and discussed in terms of the responsible component processes in the plant itself and in relation to soil atmosphere conditions. The reader, therefore, is not only presented with abstract facts, but is actually apprised of the lines of reasoning by which the author develops his comprehensive views regarding the complex associations and mutually beneficial relations existing between plant structures and the metabolic processes essential for the growth and functioning of the plant as a unit with its environment. This perspective is derived, on the one hand, from precise experimentation with highly specialized and refined techniques applied to plants or to their separate organs or tissues under strictly controlled—often artificially produced—conditions not encountered in nature but rather designed to reveal and to measure the highest potentialities of a specific process or mechanism. It is derived, on the other hand, from a wealth of greenhouse culture and large scale field experiments providing for the operation of the specific process considered under a variety of conditions both within and without what might be called a normal or natural range. By this method, which amounts to testing and tempering theoretical conclusions by practical applications, not only accuracy and completeness are assured, but a sense of reality is imparted to each phase of the subject. The net results, therefore, are generalizations which are of interest to the ecologist and practical plant biologist perhaps equally as much as to the plant physiologist and specialist in plant nutrition.

The book demonstrates in a general sense what has been attained in recent years by the application of the most modern tools of chemistry and physics to the solution of some of the oldest, most difficult, and therefore often controversial problems in plant physiology. The results are a notable achievement. It shows, further, how the solution of these classic problems has constantly demanded ramification and expansion into newer related fields of investigation, and it repeatedly points out the salient points of attack for continued future progress. Thus, for example, one lecture is devoted to a consideration of plant metabolism in relation to inorganic nutrition. In the treatment of this relatively vast field, attention is given mainly to specific problems that are now being explored or are in urgent need of solution to clear the way for further advance in the study of plant nutrition. By this procedure the author throws a searchlight on many side lines that have been followed by relatively few workers and have not received deserved attention for lack of appreciation of their fundamental general importance. These features of the book should be of value to both beginning and advanced students of plant biology.

The book also may be recommended to the general biologist, particularly to the general and animal physiologists interested in permeability or in the mechanisms of intake, retention, and secretion of materials by cells, for there can be no doubt that many principles and concepts brought to light in these studies on higher plants can be carried over, in part, to all types of organisms and offer valuable suggestions for an understanding of these and related phenomena in general.

Although the subject matter of this book in some aspects is inevitably complex, the presentation is nevertheless direct and simple. The style is authoritative, yet cautious and by no means oversimplified or "popular" in character. Any student with general training in science should find no difficulty in reading any part of it, especially as he will at no time be confronted with highly specialized technical terminology.

The general reader in particular will find the value of the book enhanced greatly by a series of 28 full-page plates illustrating equipment and results obtained in water and soil culturing of plants, as well as illustrations of nutrient element deficiencies as they occur under artificial culture and some natural conditions. Each lecture includes a literature reference list covering the topic discussed.

Although the present work is not a textbook in the usual sense, it is a comprehensive and very informative treatment of the entire subject of plant nutrition that will serve admirably both for general reading and reference.

I believe these "Lectures on the Inorganic Nutrition of Plants" will prove to be a very valuable and popular member of our plant science books.

BRIEF NOTICES

GENERAL BIOLOGY

CONSERVATION IN THE UNITED STATES. *Second Edition.*

By A. F. Gustafson, C. H. Guise, W. J. Hamilton, Jr., and H. Ries. Comstock Publishing Company, Ithaca. $4.00. 9½ x 6½; xi + 477; 1944.

The waging of modern warfare causes unexampled inroads upon the resources of a nation. The new problems of conservation now facing us because of this form the central theme of this new edition of *Conservation in the United States*, first published in 1939. The same general organization of the subject has been retained. After a brief introduction to the history of the struggle for conservation of natural resources in the United States, there are four main sections, devoted respectively to the conservation of soil and water resources (Gustafson), of forests, parks, and grazing lands (Guise), of wildlife (Hamilton), and of mineral resources (Ries).

The volume is intended to be non-technical and adapted for the general public. It certainly succeeds in being readily intelligible, but unfortunately overshoots the mark. The style is repetitious and the treatment frequently superficial. The elaboration of the obvious often reaches a point that is exasperating. This is the more unfortunate because many ideas buried in the welter of words indeed deserve the attention of our entire citizenry. Does even a child in grade school need to be informed, however, that "anyone interested in what goes on about him cannot fail to notice the extent to which metals are used in many branches of human industry, and how their use has increased our comfort and happiness in this world; in other words, how they have contributed to civilization"? The questions at the ends of the chapters are not thought-provoking, but merely call for a repetition of the text discussions.

The book is well printed and its abundant illustrations are well selected and form its most attractive feature. Proofreading has been careless, however, passing even such errors as three entire misplaced lines on page 93. A list of supplementary readings and an index are provided.

In summary, if the present contents were purged of truisms, unnecessary repetition, and excessive verbiage, and if the half of the book thus saved were devoted to a more intensive consideration of problems that are only *said* to be complex, the book would have outstanding value for an intelligent student or layman.

As it stands, it contains much of value, presents a well-rounded picture of the several aspects of conservation, and calls attention to the pressing problems due to wartime exploitation of resources.

ELEMENTS OF BIOLOGY. *A Brief Course for College Students.*

By Perry D. Strausbaugh and Bernal R. Weimer. John Wiley and Sons, New York; Chapman and Hall, London. $3.25. 8¼ x 6; vii + 461; 1944.

The co-authors of the successful college text, *General Biology*, issued in 1938, now present a revised and condensed text adapted for the semester or term course in college biology. They have wisely maintained the general organization of their larger text in the new one, devoting the first half of the book to a consideration of plant and animal metabolism and the later chapters to growth and development, heredity, classification, ecology, and evolution. The skilful correlation of plant and animal metabolism characteristic of their earlier text is further improved.

There are several changes that will be welcomed. There is a new introductory chapter on the place of biology among the sciences, its subdivisions, and the nature of the scientific method. The importance of the hormones is recognized in a full chapter. The teaching value of making the study of biology center around man himself is more fully recognized by the inclusion of two new chapters: "Biology and Human Health" deals with bacteria, viruses, immunity, animal parasites, and venomous snakes; "Man and Other Economic Relationships to Plants and Animals" briefly surveys the cultivated plants, plant diseases, destructive insects, the animal food supply, sources of clothing, etc. The overwhelming amount of morphology and technical terminology in the larger text has been drastically curtailed. The figures are largely the same, but a number of striking new diagrams have been added. The halftones are unfortunately not always sharp.

Some of the errors and objectionable statements have been carried over from the older to the new book, although others have been amended. One is glad to find the plasma membrane now included in the description of the typical cell, for instance, but sorry to see that cytological viper, the continuous spireme, still coiled in readiness to strike the unwary student on p. 196, instead of in its rightful place among the poisonous reptiles. The definitely objectionable treatment of eugenics in the older book has been carefully revised and is much more acceptable in the new. It is indeed to be hoped that the authors will now revise the larger text in the light of the improvements made in this shorter elementary biology.

BIOLOGY AND MAN.

By Benjamin C. Gruenberg and N. Eldred Bingham. Ginn and Company, Boston. $2.24. 9½ x 6½; viii + 719; 1944.

College teachers of biology should be keenly interested in many features of this new high school biology text, and it is to be hoped that it will meet with wide approval in the high schools themselves. It is written in an interesting fashion, and the avoidance of unnecessary technical terms is exemplary. The illustrations include well-chosen photographs and museum exhibits—and the amusing cartoon by Alajalov of the canine Kallikaks—together with numerous original diagrams that are often of unexcelled clarity and appeal.

The organization of the book is also outstanding, the authors having managed to make the biology of man the center of interest and the focus of teaching, without presenting general biology in an unbalanced fashion. Each chapter commences with a series of questions likely to be raised about the topic on the basis of common experience, and concludes with a series of thought-provoking questions raised in the discussion. Each chapter also has a concise summary and is provided with a list of suggested "explorations and projects" that might well offer suggestions for many college laboratories, although some of them appear to be beyond the realm of practicality.

The several units cover in succession the nature of life; the conditions of life; the maintenance of life; the integration of the organism; reproduction, growth, and development; evolution and heredity; ecological relations; and the uses of biology; with a supplement on the classification of plants and animals; a list of books for additional reading, with comments about them; and an index. It is especially gratifying, in view of the widespread failure to teach anything about evolution in many high schools of the United States, to see this subject, including human evolution, occupying a prominent position. It is also encouraging to see the study of such dynamic aspects of life as growth and development vivifying the study of morphology.

Unfortunately, the book contains a number of things to which college teachers of biology will object. For example: a diagram shows Neanderthal man with a cranial capacity below that of modern man; solutes are said to pass through membranes by osmosis; nitrifying bacteria are completely omitted from the nitrogen cycle; the continuous spireme is figured in dividing cells; ants, in contrast to human beings, are said to lack distinct individuality; Haeckel's inaccurate drawing of embryos at comparable stages is used without an adequate clarification of recapitulation. Discussions are not always lucid. In justice, however, it must be admitted that similar faults and errors occur in college biology texts with scarcely less frequency. On the other hand, the originality of this high school text

should place it on the desk of every college teacher who plans to write a text of biology. It is also to be hoped that many students in our secondary schools will get the opportunity to have their interest in biology whetted by using this text.

MODERN FARMER'S CYCLOPEDIA OF AGRICULTURE: *A Compendium of Farm Science and Practice on Field, Garden, Fruit, and Orchard Crops, and the Care, Feeding and Diseases of Farm Animals.*

By Earley Vernon Wilcox. Orange Judd Publishing Company, Inc., New York. $4.50. 9½ x 6¾; xiv + 497; 1944.

The latest pertinent scientific information on every phase of agriculture has been carefully catalogued in these 500 pages in such a manner that the finished volume is an extremely practical and useful handbook for anyone interested in farming or farm products in this country.

The first three parts of the book cover a wide variety of field, garden, and orchard crops, and present detailed discussions on such vital factors as the best soil in which to plant, the varieties best suited to various geographic localities, the time and method of planting, the use of natural or commercial fertilizers, the most suitable methods of cultivation, propagation and irrigation, the treatment of diseases and the control of common insect pests, the time and methods for harvesting and storing, the approximate yield to be expected, and the economic value of the product.

Parts IV, V and VI deal with the husbandry of domestic farm animals, and give completely scientific accounts of the selection, breeding, and care of cattle, horses, mules, swine, sheep, goats, and poultry. Special emphasis is given to the selection of varieties of stock best suited for various market purposes, and the problems of housing, feeding, and marketing.

In Part VII, the importance of fertilizers, drainage, irrigation, and soil conservation is discussed in relation to the general problem of soil care.

Part VIII covers a miscellaneous list of things which either directly or indirectly affect the welfare of the farmer. Included here are timely hints on the benefits to be derived from contacts with our agricultural colleges and experiment stations, and the economic importance of such organisms as bees, dogs, squirrels, mosquitoes, rats, toads, weeds, etc.

Five pages of tables showing times and methods of planting and times of harvesting garden crops, distances for setting out fruit trees, and weights per unit quantity of a wide variety of commodities are appended.

The complete index will serve the volume well in its use as a reference encyclopedia.

EVOLUTION

FOUNDATIONS OF PLANT GEOGRAPHY.

By Stanley A. Cain. Harper and Brothers, New York and London. $5.00. 9½ x 6; xiv + 556; 1944.

This is an important, scholarly study of the basic fields underlying Plant Geography. The material is divided into four principal topics: Paleoecology, Areography, Evolution and Plant Geography, and the Significance of Polyploidy in Plant Geography. In a sense this is a critical commentary on the development of ideas not only in plant geography, but in the allied botanical fields on which plant geography is built. There is an extensive bibliography (720 titles) and a useful glossary of technical terms. The work is technical and not intended for one unprepared in botany.

Paleoecology deals with fossil floras and the methods and problems of determining the components of such floras and their meaning. The utility of pollen analysis in such studies is carefully analysed.

Areography deals with the terms and concepts of area, dispersal and migration, centers of area, endemics, discontinuous distributions, etc. One misses here some discussion of the theory of continental drift.

The section on Evolution and Plant Geography deals with the nature of species, isolation, the causes of species stability, and rates of evolution and speciation. The significance of polyploidy in plant geography is considered from the basis of its origin, characteristics, and bearing on phylogenetic relationships.

INDEX FOSSILS OF NORTH AMERICA.

By Hervey W. Shimer and Robert R. Shrock. The Technology Press, Massachusetts Institute of Technology; John Wiley and Sons, Inc., New York; Chapman and Hall, Ltd., London. $20.00. 11 x 8; ix + 837; 1944.

This magnificant volume gives descriptions of approximately 7500 species of index fossils, with nearly 10,000 figures grouped in 303 full-page plates, excellently reproduced. Within phyla, classes, and subclasses, the genera are arranged either taxonomically or, in the case of trilobites, alphabetically, while the species are arranged within each genus in stratigraphic order, the oldest first, and geographically from north to south, from east to west. Brief discussions of the general nature of the organisms and the basis of taxonomic differentiation head each general section. The treatment of genera and species is best shown by quoting an example. The following is the description of a well-known trilobite:

ISOTELUS Dekay 1824

(**I. gigas*) Isopygous; cephalon and pygidium smooth, with brims that lack rims; hypostoma bifurcated; axial lobe of thorax wide. **Ord.** (N. America; Norway).

***I. gigas** Dekay (268—2, 3). Cephalon and pygidium elongate, the former without genal spines in the adult. **M. Ord.:** Widespread throughout N. America.

(The asterisks designate this as the genotypic species. The numbers in parentheses refer to plate and figs.)

There is an index of genera requiring 69 pages, and an index of species occupying 47. References to the literature are abundant and in the form of footnotes.

It is unfortunate that the title fails to make clear that the work, like its predecessor, Grabau and Shimer's *North American Index Fossils*, is almost wholly restricted to invertebrates. A brief section, at the end of the volume, describes a few plant fossils and miscellaneous objects, but vertebrate index fossils are entirely omitted, in spite of their great value in stratigraphic work on post-Paleozoic formations. The groups receiving major attention, in the order of their importance, are the brachiopods, gastropods, crinoids, cephalopods, pelecypods, coelenterates, trilobites, foraminiferans, ostracods, and bryozoans. The sections on several of these (Foraminifera, Crinoidea, Brachiopoda, and Paleozoic Gastropoda) as well as sections on the Conodonts, Blastoidea, Insecta, Charophyta, and Calcareous Algae, were prepared by specialists in those groups. Much other consultation and collaboration went into the work, and it stands as one of the finest examples of scientific cooperation in publication yet to appear.

A shortcoming which may seriously affect many users of the work is the total absence of keys to the genera, a lack the more surprising because of the presence of such keys in the older *North American Index Fossils*. The excellent diagrams of the characteristic arrangement of the plates of the dorsal cup in the genera of crinoids are a help, and similar diagrams are provided for some other groups, but in many groups one must hunt at random through the plates. When a group is as extensive as the trilobites, this can be very time-consuming.

Another feature of the predecessor that has been omitted is the faunal summary, a series of tables collecting the species by periods. In the new work there is no way of getting a comprehensive view of the aggregation of index fossils characterizing a single period. This seems a pity.

In spite of these minor defects, the new work is a monumental achievement. It will not only be indispensable to stratigrapher and economic geologist but will prove of great use to all students of invertebrate paleontology and evolution.

MANKIND SO FAR.

By William Howells. Doubleday, Doran and Company, Garden City, New York. $4.50. 9¼ x 6¼; xii + 319; 1944.

In a breezy style culminating in occasional wise-cracks, Howells has written a book about human evolution that is sure to be widely read. The first section of the book surveys the evolution of the vertebrates, and particularly that of the primates. The second section considers the evolution of man during the Pleistocene. The third deals with the various human races and peoples and their origins and migrations.

The first two sections, in particular, invite comparison with A. S. Romer's *Man and the Vertebrates*. The greater wealth of illustration and the more extensive treatment of fossil forms are not the only reasons for preferring Romer's book for the general survey of vertebrate and primate evolution. Howells is capable of making such a statement as the one that the upper jaw comes from the first gill arch but the lower jaw from the second (p. 19). He emphasizes the rotation of the limbs in the reptiles but ignores the far greater rotation in the origin of mammals. And he fails to credit Tarsius with stereoscopic vision. On the other hand, his account of human evolution in the Pleistocene is much more complete and well-rounded than Romer's. Pithecanthropus and Sinanthropus, Piltdown man (whom Howells, unlike Weidenreich, is not willing to dismiss as a figment of imagination), the Neanderthals, Rhodesian man, Solo man, and the early representatives of *Homo sapiens* pass in review. In a frank and entertaining manner, Howells discusses the various conflicting views held about the place of each of these in human phylogeny, skilfully weighing the worth of opposing ideas. One may only express regret that here Weidenreich's recent studies on Sinanthropus and his general conclusions as to human origins appeared too recently to be considered.

The geneticist will hardly be pleased with the ignorance of genetic fact and modern evolutionary theory which seems to be all too typical among anthropologists. There is a recurrent echo of Lamarckianism in these pages. The author's own point of view seems to be that "Not long ago it was felt that Darwin had silenced Lamarck for good, but there is now less certainty." There is frequently a tendency to minimize the role of natural selection and there is no recognition of such important evolutionary factors as parallel mutation, chance gene fixation or the relation between genes and developmental pathways that brings about consequential evolution, to use Julian Huxley's term. Instead there is only a naive faith in an unexplained orthogenesis. It seems that such books as Dobzhansky's *Genetics and the Origin of Species* and Huxley's *Evolution: the Modern Synthesis* are not yet as widely appreciated as they should be.

The chapters on human races, making up Part III, are also very readable and comprehensive in treatment, but nevertheless unsatisfactory in certain important respects. The concept of race in the human species is not clearly defined and is used both broadly, to refer to the major white, black, yellow, and Australoid

stocks, and indiscriminately to all sorts of minor subdivisions of these. Apparently Howells is by no means in agreement with such writers as Dahlberg and Ashley Montagu who disbelieve in human races altogether. Yet Howells ignores any consideration of the genetic basis of racial differences, and his own lax application of the term is not going to help in clearing the fog. Many anthropologists will also question his theory of the dispersion of all black peoples from an original home in India. Examples of parallel and convergent evolution are sufficiently numerous to make it very doubtful whether a common origin needs to be postulated.

In spite of these shortcomings, *Mankind So Far* must be listed as a most interesting and valuable book on its subject. The layman will find it paints a broad canvas in a clear and vivid manner.

GENETICS

THE MUTANTS OF DROSOPHILA MELANOGASTER. *Carnegie Institution of Washington Publication 552.*

By Calvin B. Bridges and Katherine S. Brehme. Carnegie Institute of Washington, Washington, D. C. $3.00 (cloth); $2.50 (paper). 10 x 6¾; vii + 257 + 3 plates; 1944.

The mutants of Drosophila melanogaster have been the primary tools with which the genetic architecture of the nucleus has been explored. Without them, no "mapping" of genes would have been possible, none of the intimate knowledge of chromosomal behavior obtained, no theory of the gene attempted. With much accomplished and much left for further work, the mutants remain a treasure that continues to be put to use. Up to now, most of the information regarding the mutants was scattered widely in the literature of the last thirty-five years; much was only accessible in the privately circulated Drosophila Information Service; some was known solely to a few individuals. Calvin Bridges had kept a card catalogue assembling a great deal of data. After his death, Katherine Brehme undertook the stupendous task of complementing Bridges' collection of data by making a systematic survey of all available publications on the genetics of Drosophila through December, 1942. The result is this encyclopedia of the mutants and aberrations, listed and described in the order of their symbols. A quotation shows best the scope of treatment:

w: *white* Morgan, 10e. 1–1.5. Pub. 1910, Science 32: 120–122; pub. and fig. 1916, Carnegie Pub. 237: 25 and pl. II; fig. Sturtevant and Beadle, 1939, *An introduction to genetics*, pl. 1. Eye color nearly snow white; ocelli, Malpighian tubes, and testis sheath colorless. Reoccurs very frequently and has numerous alleles intermediate between *w* and wild type. Salivary-chromosome locus in 3C2 (Schultz); see also Slizynska, 1938, Genetics 23: 291–299; by analysis of changes affecting *w*, Demerec and Sutton place locus at 3C2–3 (Demerec et al., 1942, Carnegie Year Bk. 41: 191). Prokofyeva-Belgovskaya places it at 3C3 (DIS 15: 35 [1941]). For linkage tests, the allele w^a is best, according to Bridges. Eye color autonomous when larval optic disk is transplanted into wild-type host (Beadle and Ephrussi, 1936, Genetics 21: 230). RK1.

In addition to the mutants, descriptions of wild-type stocks are given. Fifteen pages are covered by the most extensive linkage maps ever computed. Plates of Bridges' famous maps of salivary chromosomes are included. This book is not only a monument to past achievements but a necessary instrument for future work and a source of information which will be made use of by students interested in the general aspects and interrelations of genetics, development, and evolution.

CONTRIBUTIONS TO THE GENETICS, TAXONOMY, AND ECOLOGY OF DROSOPHILA PSEUDOOBSCURA AND ITS RELATIVES. *Carnegie Institution of Washington Publication 554.*

By Th. Dobzhansky and Carl Epling. Carnegie Institution of Washington, Washington, D. C. $2.75 (cloth); $2.25 (paper). 10 x 6¾; iii + 183; 1944.

In the past few years the genetics of natural populations has taken enormous strides, and its great significance for studies in taxonomy, ecology, and evolution has become obvious. Among the groups subjected to intensive study, none has offered a greater opportunity for fruitful research than the genus Drosophila, on account of the surpassing extent of the cytological and genetic knowledge previously accumulated about it, its widespread distribution, and its laboratory suitability. Dobzhansky has pioneered in the investigations of the natural populations of *D. pseudoobscura*, and through his labors and those of his colleagues, these researches, begun less than ten years ago, have already assumed a central position in genetics and the study of speciation, and a summary of the findings is sure to be of the utmost importance.

This publication contains three papers. In the first Dobzhansky and Epling consider the taxonomy, geographic distribution, and ecology of *D. pseudoobscura* and its relatives. The principal feature of taxonomic interest is the decision made by the authors to raise *D. pseudoobscura* race B to specific rank, giving it the name *D. persimilis*. Although there is no ready way of differentiating *D. pseudoobscura* and *D. persimilis* morphologically, the separation seems fully justified on cytological and genetic grounds, including the sterility of hybrid males and lowered viability of the offspring of hybrid females backcrossed to either parent form. Few workers in the "new systematics" will question this decision.

Ecologically, *D. pseudoobscura* and *D. persimilis* present a mystery in the fact that even where considerable populations subsist, no adequate supply of

their known foods is to be discovered. The adult flies show a diurnal periodicity in activity that is related to light. They migrate (at 70°F.) only about eighty meters per day from a point of release, so that the racial differentiation actually found in populations only a few miles apart, in continuously inhabited territory, can be accounted for by this low migration rate.

In the second paper, Dobzhansky reviews the studies of chromosomal races in *D. pseudoobscura* and *D. persimilis*. Most of this work, based on the distribution of inversions, is already well known, but many new data have been included. The phylogeny of the gene arrangements in the third chromosomes of the two species has been revised. There are four excellent plates showing the configurations of the salivary gland chromosomes in various heterozygous combinations of these inversions. Tabular summaries of the original data are graphically illustrated in maps that show the geographic distribution of the gene arrangement by phylads. In some directions the frequencies of gene arrangements form clines, while in others they vary irregularly, but the effort to correlate the clines with climatic and other ecological factors is only partially successful. There is another contradiction that is not resolved. On the one hand, there is an agreement within local populations between the actual frequencies of homozygotes of the various gene arrangements and the predicted frequencies on the assumptions of equal viability and panmixia. On the other hand, there are striking differences between populations only a few miles apart that would appear to imply populations of small effective size ("population number") and to render random breeding improbable; and also the existence of the clines and seasonal fluctuations in relative frequency of the gene arrangements, that would appear to indicate some differential action of selection on the very arrangements represented in the local populations. The discussion of the concept of race should be of wide interest, and the conclusion that in Drosophila intraracial variability is commensurate with interracial variability is of great significance.

In the third paper, Epling argues that the original establishment of Standard, Santa Cruz, and Tree Line arrangements, heads of the three main phylads, occurred as long ago as the Miocene. This he believes mainly because of the present disjunct geographical distribution of Santa Cruz and other members of its phylad in Guatemala, Mexico, and California, and their failure to occur in association with the present-day derivatives of the Madro-Tertiary vegetation which is thought to go back to the late Miocene in the intervening areas. The suggestion of such antiquity for these inversions is startling and may not be eventually substantiated, but it should certainly provoke a great deal of fruitful investigation.

This Carnegie Publication worthily carries on the great tradition set by its predecessors in the series, the invaluable contributions to the genetics of Drosophila made by Morgan, Sturtevant, Bridges, and Dobzhansky himself.

SEX

PROCEEDINGS OF THE CONFERENCE ON PROBLEMS OF HUMAN FERTILITY *Sponsored by the National Committee on Maternal Health, January 15–16, 1943, New York City.*

Edited by Earl T. Engle. Published for National Committee on Maternal Health by George Banta Publishing Company, Menasha, Wis. $2.00 (cloth); $1.50 (paper). 9¼ x 6½; xi + 182; 1943.

In response to a well deserved demand, the proceedings of this conference, the fourth annual one under this sponsorship, have been published in book form, thus displacing the inadequate mimeographed reports used previously. The symposium deals not with large statistical problems of population growth but rather with certain anatomical and physiological aspects of mammalian and especially of human reproduction. The emphasis throughout is on results obtained in the experimental laboratory, but there is almost continual reference to the clinic. The conference must have come close to the ideal of cooperative interchange of facts and ideas between research men and clinicians. The list of participants in the discussions runs from Boling to Wislocki and, with several exceptions, includes most of the leading American workers in the field covered. The papers themselves are more in the nature of original contributions than reviews, though they bring the topics considered up to date. The discussions are full, informal, and illuminating.

The first group of papers is on "Criteria of Ovulation." E. L. Sevringhaus discusses "Endocrine Criteria of Ovulation"; J. Rock, "Embryological Criteria as Evidence of Ovulation Time"; and W. W. Greulich, "The Age of Corpora Lutea and Timing of Ovulation." J. L. Boling ends with a paper on the still problematical question of "Electrometric Techniques Correlated with other Studies of Ovulation."

The second group of papers covers "Some Biological Observations on the Lower Generative Tract." J. K. Lamar presents "Some Observations on Sperm Migration through Cervical Mucus"; B. B. Rubenstein, "The Transport and Survival of Sperm in the Vaginal and Cervical Canals"; and A. E. Rakoff, "Present Problems Related to the Biology of the Vagina."

The final group on the "Placenta as a Barrier" consists of four papers, respectively by G. B. Wislocki on "Some Observations on the Cytology of the Trophoblast"; by F. P. Snyder on "Placental Transmission in Relation to the Stage of Pregnancy"; by A. Gelhorn on "Placental Transmission of Radioactive Isotopes";

and by B. Ratner on "The Passage of Native Proteins Through the Placenta."

There are a number of excellently reproduced photographs of unfixed ova and of various histological material, which make a welcome contrast with some war-time illustrations. The lack of an index is regrettable but not serious in a book of this type. There is, of course, a table of contents.

BOTANY

MARINE ALGAE OF THE MONTEREY PENINSULA CALIFORNIA.

By Gilbert M. Smith. Stanford University Press, Stanford University, California; Humphrey Milford, Oxford University Press, London. $6.00. 9¼ x 6½; ix + 622; 1944.

This comprehensive and authoritative book will undoubtedly establish the Monterey Peninsula as the locus classicus of the Pacific Coast for algae, since here, because of the diversity of habitat and ecological conditions, the algal flora is far richer than that of any other part of the coast, and here the most intensive work has been done by the author, during more than seventeen years of his teaching and investigation at the Hopkins Marine Station. As a result, this region is the type locality for about twenty-five per cent of the west coast species, and the nearly four hundred species and varieties included in the book comprise around eighty per cent of all that are known from Southern California to Puget Sound.

The introduction covers such general matters as a survey of previous collections and studies in the region; an explanation of the local and official names of various stations; a discussion of distribution in relation to such factors as substratum, light, wave action, and temperature; and a guide to methods of collecting and to the necessary equipment from teaspoon and stone chisel to hip boots. The glossary will prove valuable to the student and even to the investigator because its definitions include the numerous technical terms used for the complicated reproductive structures in the red algae.

The main body of the book covers the three algal divisions: Chlorophyta in fifty pages, Phaeophyta in eighty pages, and Rhodophyta in three hundred and twenty pages, this last being especially valuable because death cut short the comprehensive work of Setchell and Gardner before they were able to publish their monographic study of this group. The taxonomic treatments of the brown and red algae, based on Kylins' rearrangement, have kept pace with recent developments in our knowledge of the life histories and reproduction of these forms. The discussions of the green algae largely follow the taxonomic system previously used by the author in other texts. Keys and descriptions of classes, orders, families, genera, and species are given while each species is described and characterized with its synonymy and critical references together with any points of special interest. The distribution for the Pacific Coast as well as for the Monterey region is given, and the type locality noted.

A bibliography of fifteen pages adequately and comprehensively supports the text.

The thirteen page key to the genera gives evidence of thorough and careful going over until it is truly functional and, unlike many which have been published, may be used successfully not only by the expert who already knows the genera, but also by the beginner who does not.

The ninety-eight plates, ranging from one figure each in some of the larger kelps up to as many as fourteen figures for some of the green algae, are excellent portrayals in well executed line and stipple of the general characteristics of the plants, with the essential microscopic details of their structure and reproduction. In part the work of the author, in part of Mrs. Janish, the plates are uniformly excellent and helpful, a very valuable feature of the book.

A few criticisms are inevitable. It is difficult to see the advantage of the author's adherence to the termination *phyta* with all its implications rather than *phyceae*. The use of Blakeslee's terms homothallic and heterothallic seem questionable when heterothallic, applicable at such levels of reproduction as that of Cladophora and Spongomorpha in the Green Algae is also used in the case of such Red Algae as Laurencia and Polysiphonia. The definition of basipetalous—"with progressively younger organs from base to apex"—makes one wonder what the definition of acropetalous would be had it not been omitted from the glossary.

After Gardner's painstaking work, it is disheartening to find that this book, for some reason, ignores the occurrence of any of the Blue-Green Algae in this rich region.

To the investigator and specialist, as well as to the student, this book will prove of great value, and it sets a standard for completeness and thoroughness that subsequent monographs will do well to follow.

A DICTIONARY OF THE FUNGI.

By G. C. Ainsworth and G. R. Bisby. The Imperial Mycological Institute, Kew, Surrey. $4.60. 7½ x 5; viii + 359; 1943.

This book attempts to cover for the fungi what Willis' well-known *Dictionary of Flowering Plants and Ferns* covers for those groups. In this attempt it achieves notable success, for it is a prodigious little book that crowds a tremendous amount of useful mycological, pathological, and botanical information into its compact pocket-edition size. In it are covered all of the generic names of the fungi (exclusive of bacteria and

lichens) in use up to the end of 1939, with the synonymy of the genera and species indicated according to the rules of botanical nomenclature. Here are listed some 7200 generic names, 3625 of these being valid and tenable with 1711 monotypic, 3575 being synonymous or uncertain. For each genus its systematic position, the number of its species, its distribution and other pertinent items of information are given.

The book, despite its title, is much more than a glossary of terms, for in addition to the names of the genera and their authors, it gives the common and scientific names of important fungi, with brief but effective accounts of the chief families, orders, and classes of the fungi, as well as of bacteria and lichens.

Interspersed among the generic definitions and the descriptive terms in appropriate alphabetical order are nearly 70 sections, each a brief but very effective treatment of some fundamental subject. Among general sections may be noted excellent discussions of phylogeny, nomenclature, classification, genetics and variation, nutrition, and symbiosis. There are also sections on ecology and distribution, among them the treatments of aquatic, marine, medical, and entomogenous fungi being especially good. Excellent sections on applied mycology cover the industrial, medical and agricultural aspects, as well as mycophagy and mushroom culture. The history of mycology, with brief biographical notes on mycologists from Fries to Farlow, are included in the sections on History and Biography.

An excellent systematic background may be gained from the book, since each genus and species through cross reference is relegated to its appropriate taxonomic position, the characterizations of families, orders, and other taxonomic groups being brief but well formulated.

The included literature, if embodied in a bibliography or list of references, would make an imposing total, for there are frequent pertinent references in appropriate places that give the reader further information on a group, subject, or aspect.

An appendix of fifteen pages gives G. W. Martin's "Key to the Families of Fungi" as a convenient taxonomic system with which the student can conveniently coordinate information scattered through the book. Following this, figures 1 to 105, in nine full-page assemblies with descriptions opposite, illustrate in line drawings the chief representatives of the major groups of fungi, along with a few bacteria and lichens. The final plate, including figures 106 to 138, illustrates in outline diagrams some of the most commonly used technical terms applying to form and other structural features.

For the advanced worker as well as the student the book will be a very useful tool, compressing into its small compass an introduction to classification, an index to names, an explanatory glossary of terms, a guide to methods, and much other pertinent information valuable in itself and highly accessible. Phraseology in some instances may seem to the reader unusual, until he realizes that the writing of the book is in basic English plus international science words, with a very few non-basic words when necessary.

There is ample evidence that years of conscientious, well-planned labor went into the development of this book. Its accuracy and scope are impressive. There are few if any typographical errors, "Lagendiales", "Trisporium", and "Ostracoblade" being the only ones that have caught the attention of this reviewer. The figures, although helpful, lost in effectiveness because of their small size and diagrammatical character.

Compact, scholarly, comprehensive, authoritative, and effectively organized, this book will have wide use among workers in mycology and related fields.

ILLUSTRATED FLORA OF THE PACIFIC STATES *Washington, Oregon, and California. Volume II. Polygonaceae to Krameriaceae. Buckwheats to Krameras.*

By Leroy Abrams. Stanford University Press, Stanford University, California; Oxford University Press, London. $7.50. 10¼ x 7¼; viii + 635; 1944.

This second volume of the projected four volume *Illustrated Flora*, continuing the Choripetalae, covers thirty-five families from the Polygonaceae through the Krameriaceae, embracing two hundred and ninety-nine genera from Pterostegia through Krameria, comprising in all around 1660 species with full descriptions, synonymy, distributions, and other pertinent data. The descriptive and taxonomic text is effectively supported by 1663 illustrations, some from Britton and Brown, many original, showing in accurate line and stipple the diagnostic characteristics in habit and in minute details of floral parts and fruits necessary for identification.

Although to some extent collaborative, as in the case of C. P. Smith's treatment of the difficult genus Lupinus, the bulk of the book is by Abrams himself, the culmination of his more than forty years' study of the flora of the western United States, more than twenty-five of these being spent in the preparation of the monumental illustrated flora of which this is volume two.

Following the detailed treatment of this assembly of species, a three page index gives the literature references to the new species, sub-species, and varieties described from the region since the manuscript for this volume was completed and placed in the printer's hands in 1938. These additions are mostly new species of Lupinus in the Fabaceae, described by Smith, and new members of the Brassicaceae, described by Rollins, with a few additions in nine other families.

Reference is expedited by an adequate index of genera and families with distinctive typography setting off synonymous names.

Since this flora in a measure parallels Britton and Brown's flora of the east coast, it is of interest, in comparing the two, to note the array of the Stonecrop family in contrast to their relative scarcity in the eastern flora, and the representation of the Sarraceniaceae by the monotypic, spectacular *Darlingtonia californica* in contrast to the several less striking Sarracenias of the east coast. Significant comparisons in several fields will be facilitated by this comprehensive flora, for here the ecologist, the student of plant distribution, and the worker in comparative floras will find authentic and adequate material. For the reviewer this flora, by its very completeness, presents an awesome task comparable to that of reviewing another volume of Saccardos Sylloge in mycology or of Beilstein in organic chemistry. This volume, like the first, is in itself a significant contribution. The full four volumes making up the comprehensive illustrated flora of a rich region will, when completed, prove an authoritative and monumental contribution.

THE DIAGNOSIS OF MINERAL DEFICIENCIES IN PLANTS BY VISUAL SYMPTOMS: *A Color Atlas and Guide.*

By T. Wallace. His Majesty's Stationery Office, London. 10s. 9½ x 6; vi + 116; 1943.

This small but useful volume is one of the practical results of the attempts of the Agricultural Research Council of England to foster better agriculture under war conditions by making available to farmers and others concerned with crops all available information for the improvement of production.

The book features the method, largely developed by the author, of diagnosing the nutrient deficiencies of soil areas from such visual symptoms as changes in color, in texture, and in method of development of leaves and other plant parts. This practical method is shown to be applicable to commonly grown crops, as well as to the series of indicator plants selected by the author after many trials.

Facilitating the recognition of diagnostic symptoms by agricultural advisors, farmers, and growers not specialists in plant physiology, the outstanding feature of the book is the inclusion of 114 reproductions in color illustrating the effects of deficiencies in such common and important crops as cereals, cruciferae, beets, beans, potatoes, tomatoes, gooseberries, hops, and apples. The first six of these depict potato plants, showing changes in color and development symptomatic of deficiencies in nitrogen, phosphorus, calcium, magnesium, or potassium in contrast to the normal plant to which complete nutrient has been available. To prevent confusion in distinguishing deficiency symptoms, the results of injury from virus diseases and insects are also shown.

The text of the book ably supports the plates, furnishing a brief but thorough background for the reader who has not had the benefit of training in the nutritional physiology of plants. Two introductory chapters on the nutrition of plants and on soil in relation to the supply of mineral nutrients are followed by a discussion of the methods of determining mineral deficiencies in crops, with special emphasis on the use of visual symptoms of deficiencies for diagnosis in the field, supplemented by test plots using indicator plants together with fertilizer treatments.

This book is most timely, for it will serve a specially valuable purpose now when a considerable acreage of land, comprising a wide variety of soils long without crops, is being cultivated under war conditions. It furnishes a quick, practical method of facilitating early recognition of mineral deficiencies even by relatively untrained workers, so that suitable remedial measures may be applied in time to save a valuable crop.

PLANTS AND FLOWERS IN THE HOME.

By Kenneth Post. Orange Judd Publishing Company, New York. $2.00. 8 x 5½; xiv + 198; 1944.

From the practical information included in this attractive little book almost anyone should be able to grow plants successfully in the home. In view of the great importance of selecting the right plant for the environment it is expected to grow in, the author furnishes a rather complete list of flowering and foliage plants that can be grown satisfactorily indoors. Both scientific and common names are given. After a brief description of each plant, mixed information is furnished concerning its propagation, culture, care, and the troubles that may be encountered in the form of diseases and insect pests.

Separate chapters are devoted to the general care of plants, as regards watering, repotting, pinching, etc. Information concerning the preparation of dish gardens, water gardens, and window boxes, and the arrangement and care of cut flowers is also included. One chapter is devoted to the common house-plant diseases, insect pests and their control. The photographic illustrations are numerous and helpful. There are plant and subject indexes and a glossary.

UNIVERSITY OF CALIFORNIA PUBLICATIONS IN BOTANY. *Vol. 18, No. 12. Chromosomes and Phylogeny in Crepis III. The relationships of One Hundred and Thirteen Species,* by E. B. Babcock and J. A. Jenkins. *Vol. 18, No. 13. Chromosome Numbers in the Hydrophyllaceae: II,* by Marion S. Cave and Lincoln Constance.

University of California Press, Berkeley and Los Angeles. No. 12, 75 cents; No. 13, 25 cents. 10½ x 6½; No. 12, 52; No. 13, 6; 1943, 1944.

ZOOLOGY

THE CANVASBACK ON A PRAIRIE MARSH.

By H. Albert Hochbaum. American Wildlife Institute, Washington. $3.00. 9 x 6½; xii + 201; 1944.

The Delta Marsh, to the south of Lake Manitoba, is a common breeding ground for ten species of ducks. For the last ten years it has also been the site of a duck hatchery sponsored by Mr. James Ford Bell, and since 1938 the American Wild Life Institute has cooperated in its maintenance, and Mr. Hochbaum has been engaged there in a study of the cycle of duck activity from spring till autumn.

This book giving the results of his investigations makes a substantial contribution to the natural history of ducks, and also to problems of the conservation and management of waterfowl resources.

Attention is focused on the Canvasback, with subsidiary references to other species. The ground covered includes sex ratios, courtship, the behavior of mated pairs and unattached ducks and drakes, territory and nesting requirements, broods, and the events of the post-breeding season. The discussion points not only towards further scientific problems but also towards practical measures in regard to conservation and shooting laws.

One of the conclusions, for instance, is that the occupation of all suitable territorial ground is more likely to limit the population of an area than is inadequate nesting-cover. This conclusion not only provides a new basis for estimating the capacity of a breeding site and the extent to which it is "saturated," but also suggests means of increasing or decreasing the population of some areas by control of territorial factors.

The subject-matter is attractively presented and emphasized by a number of clear diagrams, and in addition by the author's delightful drawings. The only fault, for the reviewer, is in the arrangement of the species list in Appendix II, which would be much more convenient for reference if it were in alphabetical order. Both the sponsors and the author of this work are to be heartily congratulated.

PRACTICAL PIGEON PRODUCTION: *A Practical Manual and Reliable Handbook on Squab Production as a Profitable Enterprise.*

By Sheppard Knapp Haymes. Orange Judd Publishing Company, Inc., New York. $2.00. 8 x 5½; xv + 263; 1944.

Those who are interested in raising pigeons for squab production will find all the necessary information in this manual, which is primarily intended for the novice. Selection of breeders, keeping records, the squab market and market prices, housing, sanitation, diseases, and feed are but some of the items touched upon. There are also remarks on the different breeds of pigeons and the use and care of homing pigeons. Consequently all the essentials needed for successful squab raising, except experience (which the writer wisely stresses) are to be found in this useful and profusely illustrated guide.

THE FISH GATE.

By Michael Graham. Faber and Faber Ltd., London. 10s 6d. 8¼ x 5½; 196; 1943.

Although the fishing industry of England suffered many hard times prior to the first World War, they were all followed by periods of recovery. But later, inquiries by Royal Commissions or Parliamentary Committees in the period between the wars revealed that the industry was suffering from an inherent sickness not occasioned by nor connected with the widespread post-war depression. The stock of trawlable fish was no longer at a paying level, expansion to new areas was checked; as a consequence profits fell, accompanied by a serious decline in fishermen. In analysing the factors underlying the resolution of this problem, the writer first provides a background to the industry itself, from the economics of the fish market down to the influence caused by the housewife's method of choosing her fish food. The inland transportation of fish, the fishermen with their boats and methods of fishing, their competition and dangers, are all artistically woven into the argument. Finally the fish in the sea are discussed, the biological research made on their ecology, and the disharmony wrought by overfishing. The Great Law of Fishing is stated in a few words: "Fisheries that are unlimited become unprofitable." In his chapter on theory the writer demonstrates the methods of calculating rate curves to determine the proper fishing intensities. All of this leads to the inescapable conclusion that fishing load must be moderated. But the proper methods of control are complex; they are well described from a philosophical as well as practical viewpoint. Those interested in the future of the great fishing industry should read this book to get a fresh slant on the problem. Even though confined to English fisheries, it is equally applicable to all countries bordering the sea.

A BIOLOGICAL SURVEY AND FISHERY MANAGEMENT PLAN *for the Streams of the Lake Superior North Shore Watershed. Technical Bulletin Number One.*

By Lloyd L. Smith, Jr., and John B. Moyle. Minnesota Department of Conservation, Division of Game and Fish, St. Paul. Free (paper). 9 x 6; 228; 1944.

The North Shore watershed of Lake Superior covers approximately 2400 square miles and extends 15 to 25 miles back from the lake shore. Twenty-eight major streams and a number of smaller creeks drain

this area. An extensive survey was made of all the important streams and the results are given in detail. Recommendations are made for the improvement of the streams for trout production, a species for which these waters are primarily suited. These policies were actually followed out on one stream, the Knife River, but could not be extended because the war curtailed field activities. This project will therefore become a guide for future planning.

In a review of the fish management policy adopted, physical, chemical, and biological conditions necessary for the successful propagation of trout are discussed. Artificial stocking is advocated for streams having (1) inadequate reproduction, caused by poor spawning areas, or loss of redds or fry by floods, (2) extreme fishery pressure reducing spawning stock, and (3) fishery loads requiring more fish than the natural productive capacity of the stream. All 7- to 9-inch fish should be planted in spring or during the fishing season; fingerlings during September. Two or more partial stockings are preferred to a single spring planting. Other recommendations and policies are discussed.

There is a useful section on the construction of revetments, dams, and deflectors, a bibliography, and appendices in tabular form giving the recommendations for fish planting for the various stream systems, as well as physical and biological data. Fish managers will derive much practical information from this bulletin, especially with regard to trout production.

STUDIES ON THE PACIFIC PILCHARD OR SARDINE (SARDINOPS CAERULEA). *Special Scientific Report No. 19 (1), Structure of a Research Program to Determine How Fishing Affects the Resource*, by Oscar E. Sette; *No. 20 (2), Determination of the Age of Juveniles by Scales and Otoliths*, by Lionel A. Walford and Kenneth H. Mosher; *No. 21 (3), Determination of Age of Adults by Scales, and Effects of Environment on First Year's Growth as it Bears on Age Determination*, by Lionel A. Walford and Kenneth Mosher; *No. 22 (6), Thermal and Diurnal Changes in the Vertical Distribution of Eggs and Larvae*, by Ralph P. Silliman; *No. 23 (4), Influence of Temperature on the Rate of Development of Pilchard Eggs in Nature*, by Elberg H. Ahlstrom; *No. 24 (5), A Method of Computing Mortalities and Replacements*, by Ralph P. Silliman.

Fish and Wildlife Service, U. S. Department of the Interior, Chicago, 54. No price; issued in limited quantities. 10¾ x 7¾; No. 19, 27; No. 20, 19; No. 21, 22; No. 22, 17; No. 23, 26; No. 24, 10; 1943 (paper).

Any fish population that is at or near equilibrium in a natural environment will naturally become unbalanced whenever the added artificial factor of fishing by man takes place. Most uninitiated laymen would immediately assume that the result is a decrease in the fish stock. While this is true if the fishing load is too severe, yet a mild fishery has a beneficial effect in reducing the population pressure. Just what intensity of fishing will produce a maximum number of fish is one of the objectives of this study. The problem is by no means simple, as a maximum increase in fish does not necessarily mean that the fish will be of optimal size from an economic standpoint. Part 1 of this report gives an idea of the complexities encountered in trying to solve the above problem. In outlining the research program, Sette gives the lines of attack to be pursued, their reliability, their varying factors, and their chances of success.

Part 2 and 3 give sufficient evidence to show that the scales of fishes can be used to determine their ages. A good deal of training appears necessary for accurate results, but the writers have gone to much trouble to check the reliability of their determinations. Part 4 demonstrates that the time required to reach a given stage of development increases about 7.15% for each 0.5°C. decrease in temperature. Other data on rate and time of spawning are given, as well as illustrations of the developmental stages.

Part 5 gives a statistical analysis to estimate natural mortality, fishing mortality, and rate of recruitment, provided age composition of the commercial stock, total catch per season, and relative amount of effort expended are known. These factors are based on the assumptions that fishery effort is uniformly distributed and that instantaneous competition between units of gear is absent. As a basis for predicting the proper depths to which to seine for regular surveys, the results given in Part 6 show positive correlations of egg and larval concentrations with temperature, and a negative phototropism of larger larvae.

This proposed project has made a good start and will undoubtedly form a major contribution to fishery biology. These reports were mimeographed for reasons of economy and to prevent delay in publication. In the copies at hand several pages were left blank; perhaps in the future the results can be collated and published in better form.

CLINICAL PARASITOLOGY. *Third Edition, Revised. By Charles Franklin Craig and Ernest Carroll Faust. Lea and Febiger, Philadelphia.* $9.00. 9½ x 6½; 767; 1943.

This text in its third edition continues to be one of the leading textbooks in parasitology. Its title is, however, misleading because it is not a clinical text in the usual sense of the word. Rather, the systematics, morphology, and biology of the helminth and protozoan parasites of man and of the arthropod vectors of other human diseases are quite fully presented. The pathology and the main clinical manifestations of the parasitic infections are likewise

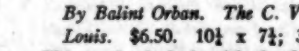
presented, but the problems of differential diagnosis are scarcely mentioned. The clinician would find the book useful for his understanding of the infections but would scarcely find it the direct answer to his clinical needs. The book is, however, effectively written from the biological viewpoint for the medical student, practitioner, and student of parasitology and is an effective reference book. While not intended in any sense as a laboratory manual, nevertheless it could be made more valuable to the student or isolated practitioner if the drawings of the organisms were supported by the labeling of component parts. While the reviewer would not agree with some of the statements, such as those concerning the role of the male in the parasitic generation of Strongyloides, such disagreements would largely be the result of honest differences of opinion, and the reviewer believes it to be the most authoritative text in medical parasitology.

UNIVERSITY OF CALIFORNIA PUBLICATIONS IN ZOOLOGY. *No. 48, No. 2. Systematic Review of the Chipmunks (Genus Eutamias) of California*, by David H. Johnson. *Vol. 49, No. 8. The Structural Characteristics and Nuclear Parasites of Some Species of Trichonympha in Termites*, by Harold Kirby.

University of California Press, Berkeley and Los Angeles. Vol. 48, No. 2, $1.00 (paper); Vol. 49, No. 8, $1.25 (paper). 10¼ x 6½; Vol. 48, No. 2, 76 + 1 plate; Vol. 49, No. 8, 98 + 11 plates; 1943; 1944.

CHECKLIST OF THE COLEOPTEROUS INSECTS OF MEXICO, CENTRAL AMERICA, THE WEST INDIES, AND SOUTH AMERICA, PART I. *United States National Museum Bulletin 185.*

By Richard E. Blackwelder. Smithsonian Institution, United States Government Printing Office, Washington. 35 cents. 9¼ x 6; xii + 188; 1944.



MORPHOLOGY

ORAL HISTOLOGY AND EMBRYOLOGY.

By Balint Orban. The C. V. Mosby Company, St. Louis. $6.50. 10¼ x 7½; 342; 1944.

This textbook deals with the development and microscopic anatomy of the structures contained in and forming the oral cavity of man, paying special attention to the dental apparatus. Nineteen authorities in various phases of dentistry have contributed the different chapters, which are clearly written, up-to-date, and supply a great amount of detailed information. Of outstanding value are the 262 well-selected and perfectly reproduced illustrations. Each chapter is concluded with remarks on "the clinical application of the basic biologic principles" of the normal structures described. The first chapter opens with the truism that "Knowledge of the embryology of an organ is essential for an understanding of its structure," but nothing is said of the evolutionary development of organs that is equally revealing and, unfortunately, there are almost no comparative-anatomical facts mentioned even in the discussions on teeth. All chapters contain brief lists of selected references to the literature, but the titles of papers in foreign languages are given only in English translation—an innovation which mars an otherwise scholarly work.

This volume can be highly recommended not only to dental students, but also to all research workers interested in human teeth.

ATLAS OF THE MOUTH AND ADJACENT PARTS IN HEALTH AND DISEASE.

By Maury Massler and Isaac Schour. American Dental Association, Chicago. $2.50. 11¼ x 8½; 49 plates with text; 1944.

Our mouth and teeth are the seat of frequent trouble and are readily inspected. Hence a collection of pictures showing the construction of our oral cavity under normal and abnormal conditions should have a considerable popular appeal. This atlas of the mouth contains 180 illustrations, of which nineteen are in color. These figures represent not only the main anatomical features of the entire dental apparatus, the tonsils, sinuses, salivary glands, tongue, facial blood vessels, muscles and nerves, but also such aspects as growth, occlusion and erosion of the teeth, effects of the loss of teeth, caries, fluorosis and periodontal disease, systemic disturbances of the tongue, facial asymmetry, and fractures of the mandible. All these figures have been drawn in superb fashion, are on a large scale, and are carefully reproduced. They are clearly and adequately labelled, and all are accompanied by explanatory text, limited to essentials.

This atlas will be useful for students of dentistry and of medicine and should greatly interest the educated layman. The book lacks a subject index.

MANUAL OF HUMAN PROTOZOA *With Special Reference to Their Detection and Identification.*

By Richard R. Kudo. Charles C. Thomas, Springfield, Ill. and Baltimore, Md. $2.00. 8 x 5½; ix + 125; 1944.

This little book fulfills the requirements of a useful manual. It presents concise descriptions of the human protozoa and some of the procedures of identification. However, it will probably be disappointing to the inquisitive or advanced student who desires to

know more about their detailed morphology and life cycles. Although the manual is designed to give the essential facts necessary to detect and identify the various organisms, a person unacquainted with the field should not be misled into believing that it contains all that is needed to accomplish correct diagnosis. It is one thing to read a vivid description, and still another actually to see and recognize the morphological structures under the microscope. Many hours of laboratory practice, preferably under the personal direction of an experienced instructor, are required before a person should rely upon his own judgment in diagnosing the human protozoa. Dr. Kudo would be the first to agree with this statement.

The text is illustrated by 29 figures. Each figure consists of several drawings of each particular organism as seen in different kinds of preparations. The magnification of most of the figures is the same (1150 ×), a convenience which will help the student in becoming familiar with the relative size of the various protozoa. Nevertheless, as a result of maintaining the same magnification, the drawings of some of the smaller specimens lack clarity of detail. In most instances, the accuracy of the figures cannot be criticized, but the gametocytes of the malarial parasites are not entirely correct. They appear to have light, clear areas in the cytoplasm that give the impression that the gametocyte contains vacuoles such as may be present in old trophozoites. Colored plates, no doubt, would have improved the representation of the malarial parasites. The manual possesses an index.

MORPHOLOGY AND DEVELOPMENT OF NOSEMA NOTABILIS KUDO *Parasitic in Sphaerospora polymorpha Davis, a Parasite of Opsanus tau and O. beta. Illinois Biological Monographs Volume XX, Number 1.* *By Richard R. Kudo. University of Illinois Press, Urbana.* $1.25 (paper). 10½ x 7; 83; 1944.

Cases of hyperparasitism are always of interest to biologists. The one reported in this monograph is especially interesting, in that a microsporidian protozoan, *Nosema notabilis*, is described as an intracellular parasite of another protozoan parasite, *Sphaerospora polymorpha* Davis, a myxosporidian. According to the author, there have been four previous reports of hyperparasitism of parasitic protozoa by microsporidians. The present is the only one in which the hyperparasite has been shown to be pathogenic to its host. In addition to descriptions of *N. notabilis* and its life history, descriptions are given of the bladders of the toadfish *Opsanus tau* and *O. beta* in which the parasites occur and of the life history of *Sphaerospora polymorpha*. The behavior of the chromosomes in the nuclear divisions of the latter are particularly stressed.

PHYSIOLOGY AND PATHOLOGY

ANNUAL REVIEW OF PHYSIOLOGY. *Volume VI. Edited by James Murray Luck and Victor E. Hall. American Physiological Society and Annual Reviews, Inc., Stanford University, California.* $5.00. 8¾ x 6; viii + 630; 1944.

This series of reviews is now thoroughly established and recognized as an indispensable reference for workers in all branches of physiology and zoology. It is therefore timely to consider possible defects in the plan of the reviews, defects which might be remedied in future volumes. The authorship continues to be authoritative, and the subjects cover the field of physiology most admirably. There is, however, considerable unevenness in the character and consequently in the usefulness of the reviews. This can best be shown by arranging the subjects treated in the present volume in the order of the number of references surveyed in each, together with the number of pages of text in the review.

Metabolic Functions of the Endocrine System. F. G. Young. Ref. 401. Pages 44½.
Growth. Neoplastic Growth. J. Furth. 290. 36.
Reproduction and Its Endocrine Control. A. S. Parkes. 244. 26½.
Blood. A. J. Quick. 235. 17.
Industrial Physiology. E. Simonson. 231. 27½.
Developmental Physiology. V. Hamburger. 215. 18.
Kidney. E. Braun-Menendez. 209. 23.
Heart. R. Ashman. 179. 24½.
The Physiology of the Skin. S. Rothman and P. Flesch. 136. 26.
Tissue Water and Electrolyte. D. C. Darrow. 133. 23.
Digestive System. B. Slutzky and A. C. Andersen. 131. 18.
Physiological Effects of Heat and Cold. J. Field, 2nd and V. E. Hall. 129. 22½.,
Respiration. T. Bernthal. 126. 36.
Energy Metabolism. M. Kleiber. 125. 28.
Visceral Functions of the Nervous System. B. A. McSwiney. 115. 22.
Vision. F. W. Weymouth. 111. 33.
Liver and Bile. L. A. Crandall, Jr. 78. 15.
Conduction and Synaptic Transmission in the Nervous System. D. P. C. Lloyd. 73. 14.
Physiological Psychology. W. Freeman and J. W. Watts. 52. 24.

It is readily apparent that there is little uniformity in the relation between the scope of the reviews and the space they consume. One contribution reviews 52 papers in 24 pages while another reviews 235 papers in 17 pages. One cannot, of course, maintain that all papers are either of equal length or importance. However, we are dealing with large enough samples here to have at least roughly comparable groups, and the significance of the comparison becomes further apparent when one consults the reviews themselves. A review with more than ten references cited per page tends to become little more than a list of references with a statement of the principal finding of each—

no discussion; no critical evaluation. There is much more scope for description and critical analysis where the ratio of space rises to five references per page. One paper actually has a ratio of only slightly over two references per page, probably an unwarranted share in so necessarily limited a volume as this. It is greatly to be hoped that the editors will in future find some way to encourage the contribution of the fuller and more critical type of review.

STUDIES ON THE PHYSIOLOGY OF THE EYE: *Still Reaction, Sleep, Dreams, Hibernation, Repression, Hypnosis, Narcosis, Coma, and Allied Conditions. Second Reissue with Supplements and New Index.*

By J. Grandson Byrne. H. K. Lewis and Company, Ltd., London. 10 x 6½; xii + 469; 1942.

This book does not deal with the function of the eye as a sense organ but with the movements of the eye and associated structures insofar as they are controlled by nerves of the autonomic system. It is a reissue with supplements and a new index. The volume is subdivided into four parts. Part I, entitled "Paradoxical pupillary phenomena following lesions of the afferent paths," is a republication of material which appeared originally in the Amer. J. Physiol. between the years 1921 and 1929. The author claims that after section of the sciatic nerve or certain dorsal roots there is a loss of tonic discharge over the sympathetic fibers to eye structures, and these muscles soon become hypersensitive to adrenalin. Section of proprioceptor afferents from the eye muscles, antigravity leg muscles or section of other proprioceptor paths abolishes or reduces tonic discharge over the parasympathetic nerves to the eye and renders the muscles innervated by these fibers hypersensitive to miotic drugs. Parts II, III, and IV are composed of a series of articles which the author wrote but was too busy to publish before compilation of this book. Part II deals with the control of palpebral, pupillary, and lens widening and closing (narrowing), and with the control of exophthalmos and enophthalmos. Although different muscles are studied, this is, to a large degree, a repetition of Part I and a restatement of general conclusions. The chapters of Part III contain descriptions of experiments which indicate that the sympathetic and parasympathetic supply of the eye structures act reciprocally. In Part IV the author classifies various pupillary reflexes and the somatic motor reflexes which he associates with each pupillary reaction under the headings of Avoidance and Approach mechanisms. He then proceeds to a discussion and interpretation of the still reaction, sleep, dreams, hibernation, repression, hypnosis, narcosis, coma, and related conditions which are supposedly related to the pupillary reactions. In addition to being rather tenuous and imaginative, much of this section is irrelevant to the physiology of the eye. The first supplement describes results obtained from some poorly done stimulations of the cerebral cortex of cats and dogs. The second supplement contains another repetition of much of the material already outlined in the body of the book.

The chapters are not dated, and consequently one is somewhat at a loss in judging the book. Some of the work must have been original and new when first done, but in the light of present knowledge the discussions and conclusions are antiquated and one infers that the author has ignored the recent advances in our knowledge of the function of the autonomic nervous system, chemical mediation of the nerve impulse, and denervation-sensitization of tissues. Many statements and observations made by the author are correct and much of the physiology discussed is well known and accepted, but the reviewer entertains some skepticism concerning the correctness of many conclusions drawn. The vast amount of repetition is inexcusable. A greater service could have been done physiology had the author merely summarized his evidence and conclusions and interpreted his observations in the light of recent work done by others. As the book now stands, it would misinform one who is not thoroughly familiar with the subject. Individuals who have worked in the fields of autonomic and central nervous system physiology might find things of interest in this volume, but the reviewer does not recommend the book to any other group.

VASCULAR RESPONSES IN THE EXTREMITIES OF MAN IN HEALTH AND DISEASE.

By David I. Abramson. The University of Chicago Press, Chicago. $5.00. 9¼ x 6½; x + 412; 1944.

The first two chapters of this book contain an adequate, though elementary and somewhat sketchy, description of the anatomy, innervation, and physiology of the peripheral vascular system. The remainder of the volume consists of an excellent summary of present knowledge of the vascular changes which normally occur in man. It deals with the responses to changes in posture, exposure to heat and cold, exercise, anoxia, and the ingestion of food. The peripheral vascular effects of gestation, various hormones, drugs, and gases are described. The last half of the book is devoted to a discussion of peripheral blood flow as affected by systemic diseases, cardiac disorders, arteriolar disease, and diseases of the veins.

Among the things which should render this book of unusual value to clinicians are: first, the descriptions and critical evaluations of methods used in the study of peripheral vessels and the blood flow therein; and second, a discussion of the methods used in the treatment of vascular disorders. Although no new infor-

mation or interpretations are presented, this book should also be of great value to the physiologist as a reference source. All students will find it to be an excellent summary with which to supplement textbook presentations of peripheral blood vessel physiology. The inclusion in the index of the names of those numerous investigators to whose work the author has referred tends to annoy one who is merely interested in locating certain items of subject matter which the volume contains. The presentation of the subject is so clear and the information so well handled that this book is highly recommended to physiologists, students, and clinicians.

FOOD INSPECTION NOTES. *A Handbook for Students. By H. Hill and E. Dodsworth. H. K. Lewis and Company, Ltd., London.* 6s. 6¾ x 4¼; vii + 121; 1943.

Public health students have long had to delve into many weighty, though excellent, volumes and sift the grain from the chaff to extract the knowledge which they seek in order to pass essential examinations. Similarly, the qualified and experienced official often requires to be reminded in a speedy manner of an essential point of food inspection work. The present concise, clearly-written and authoritative little volume should make the work of both student and official more pleasant and efficient. There has long been a need for just such a book as this, and the authors have designed it with the above end in view.

This little volume is an excellent condensation of present-day knowledge of foods and their inspection, lucidly and succinctly presented and stripped of all superfluous matter. Meat inspection is thoroughly discussed, including sections on ante-mortem inspection, slaughterhouses, slaughtering and dressing, inspection of carcasses, and anatomy and physiology. There is extensive treatment of the various important diseases of food animals and the role of the inspector in relation to them. Then follow chapters on poultry, rabbits and game, fish and shellfish, milk and milk products, miscellaneous foods, food poisoning, and food sampling. All of the material is attractively presented and readily accessible. Some of the information is given in tabular form. There is a complete index.

HEALTH FOR THE HAVING: *A Handbook for Physical Fitness.*

By William R. P. Emerson. The Macmillan Company, New York. $1.75. 7¾ x 4¾; xi + 146; 1944.

This small volume is an elementary guide to healthful living, written for the unscientifically trained. Its chief aim is to enable the reader to identify and correct "faulty health habits." The author has compiled a check list of twenty of these habits that he considers the most common, from which the reader may estimate his own Health Intelligence Quotient. Explanation of what a physical fitness or health examination should include is given, and the forms commonly used for such examinations are included in the text. Topics such as budgeting one's time, underweight correction, overweight correction, blood pressure, food and eating habits, rest, exercise, fatigue, and longevity, are discussed from a practical point of view. Included in the appendix are tables of 100 calorie portions of common foods, height and weight tables, and an individual weight chart. There is also an index.

HEALTH FOR YOU.

By Katharine Bruderlin Crisp. J. B. Lippincott Company, Philadelphia. $1.80. 8¼ x 5¼; xv + 576; 1944.

This excellent text has been prepared primarily for use as a high school text for courses in health education, and incorporates many of the fine features of the author's earlier text, *Be Healthy*. The subject matter is presented in a style of marked clarity and simplicity, and is arranged in such a manner as to be readily adapted to a wide variety of teaching methods and student abilities.

The first three sections of the text deal with the important aspects of personal hygiene. Detailed consideration is given to the structure, function, and hygiene of various parts of the body, as well as the several physiological processes of the body in relation to health and hygiene. Not only the theory, but also the practice of good health habits is emphasized in these sections.

The last two sections deal with personal health as related to public health, and health as related to safety. Emphasis here is placed upon cooperative effort in preserving the health of the community, and on the importance of accidents as an everyday health hazard.

The subject of sex hygiene is covered in a separate pamphlet entitled "Growing into Maturity," which is furnished free to users of the text.

The text is abundantly and beautifully illustrated with line drawings and photographs. Each chapter closes with a list of references and films suitable for further study of the subject under consideration. A list of some 90 health books and publications, a list of organizations concerned with the production and distribution of health films, a helpful self-pronouncing glossary, and a complete index are appended.

The work will not only serve its purpose well as a text in the field of health education, but should fill a definite need in the home library as well.

INTRODUCTION TO MICROORGANISMS.

By LaVerne Ruth Thompson. W. B. Saunders Company, Philadelphia and London. $2.75. 8 x 5½; xi + 445; 1944.

For the student with little or no scientific background who is required to study microbiology, this textbook seems to be admirably done. Presumably designed for nurses, it might profitably be used in home economics courses and might also be useful as a reference book in the high school library or hygiene course.

It is practically and clearly conceived and written, being informative without being very technical or too detailed. The subject is presented definitely from the point of view of the public health educator rather than from that of the bacteriologist. It really is an introduction to public health bacteriology, with appropriate additions concerning non-bacterial infections. The chapter bibliographies provide ample possibilities for any student who wishes to read further on a particular topic.

After each of four sections of the book there are suggestions for "laboratory experience," which are less well done than the subject matter. Most instructors would prefer or even be obliged to plan their own laboratory work according to available hours, materials, size of classes, etc., regardless of instructions included in a textbook.

The printing and make-up of the book are excellent. The illustrations are most attractive and interesting. It is adequately indexed.

VIRUS DISEASES IN MAN, ANIMAL AND PLANT.

By Gustav Seiffert. Translated by Marion Lee Taylor. Philosophical Library, New York. $5.00. 9½ x 6; ix + 332; 1944.

The contents of this book are explained as being "a survey and reports covering the major research work done during the last decade." The first ninety pages are devoted to general considerations of the nature of viruses and of the immunology and epidemiology of virus diseases. This section is followed by a catalogue of diseases of known or suspected virus etiology and those caused by "virus-like" organisms. There is a brief chapter on filtrable forms of bacteria and then a concluding section on methods.

The broad conception and plan of the book are better than the actual presentation of material. On the title page, information is not offered that the decade of virus research mentioned ended in 1937. At any rate, references to publications after that year are rare and, consequently, much contemporary work is not covered. For example, in discussing the morphology of viruses, the electron microscope work is not included.

In addition to the fact that it does not cover any very recent work, the book is unsatisfactory in certain other respects. In the table of contents, an unwary reader might be lead to believe that diseases similar to epidemic encephalitis would include not only St. Louis virus infection, but also whooping-cough, rabbit papilloma and possibly jaundice of silkworms. The form is such that section headings and subheadings are not obviously differentiated. There are numerous typographical errors. The type is large and easily read, but the printing is not uniform. The subject index is quite brief; there is no author index.

The translation seems to be exceedingly literal, no attempt having been made to translate the text into smooth English. Apparently there is frequently a poor choice of words; certainly the expression of meaning tends to be confused as well as ungrammatical.

These unfortunate characteristics make the book inferior to the more up-to-date *Virus Diseases*, published by members of the Rockefeller Institute in 1943. The latter book, although more brief, is a scholarly presentation written in a clear, concise style. On the subjects treated, it is more informative to the casual reader and to the student of infectious diseases.

THE RIDDLE OF CANCER.

By Charles Oberling. Translated by William H. Woglom. Yale University Press, New Haven; Oxford University Press, London. $3.00. 9½ x 6½; vii + 196; 1944.

No more effective or gripping an introduction to the problems of cancer could be offered a novice in the field than this short book by the eminent former chief of the Experimental Department of the Cancer Institute of Paris. The superb translation by Woglom far surpasses the English versions of most foreign scientific books. There is an extensive bibliography of the subject and an index.

An introduction dealing with the statistics of cancer is followed by a brief history of the development of ideas concerning the malady, and a well balanced consideration of the historic hypotheses concerning its causes. The main body of the book contains an equally admirable account of cancer research with both transplantable tumors and induced ones. Here the various factors known to influence the incidence of cancer are discussed, from x-rays and carcinogenic hydrocarbons to parasites, viruses, and genes. Only the sex-hormones seem to be slighted in the amount of attention they receive (two pages), considering the volume of significant work done with them.

The last chapter of Oberling's discussion is definitely the least satisfactory, and not so much because he here wholeheartedly espouses the virus hypothesis—which has, as he claims, received strong support in the last few years—as for logical reasons. Oberling is on the search for a single cause of cancer. In

pursuing this quest, he seems to fail to distinguish between *essential factors* in the causation of malignant neoplasms and the *immediate cause of incidence*. Thus he rules out genetic factors as *the* cause of cancer because individuals who possess hereditary susceptibility may or may not develop malignant tumors; while on the other hand he holds that a virus may be *the* cause, since even carcinogenic chemicals or other agents perhaps succeed in inducing a cancer only when a widespread virus is present. But surely, if the carcinogens succeed in inducing cancers in 100 per cent of trials, such a virus, which of itself does not always produce cancer, must be classed as an essential factor rather than the cause of incidence, and the virus is then in the same position as hereditary susceptibility. One also suspects that in the effort to establish the virus hypothesis, Oberling knocks down opposing theories too easily. This is certainly so of the theory of somatic mutation, the arguments against which will scarcely appear compelling to a geneticist.

In spite of the ardent partisanship which in the last chapter weakens the author's presentation, this book is to be recommended most highly to all interested in cancer. Few volumes have succeeded so well in catching the spirit of science, in depicting its methods, its successes, and its difficulties. It should afford true inspiration for the beginner in research and the more advanced scientist alike.

THE HISTORY OF MINERS' DISEASES: *A Medical and Social Interpretation.*

By George Rosen, with an introduction by Henry E. Sigerist. Schuman's, New York. $8.50. 9½ x 6½; xii + 490; 1943.

In a first part, which constitutes about a fourth of the book, Rosen gives a survey of mining and miners' diseases from neolithic times to the end of the eighteenth century. Of particular interest is his analysis of the two Renaissance classics on miners' diseases: Agricola and Paracelsus, both of which are accessible in good English translations. Agricola's *De re metallica* has been translated by Herbert C. and Lou H. Hoover; Paracelsus' *Bergsucht*, by Dr. Rosen himself.

The extreme richness of the material obliges the author to limit his field, in the second part, to the history of coal mining and the diseases of coal miners from 1800–1900. In great detail the author follows here the piercing of the mystery of the "collier's lung," as reflected especially in the work of English and German authors.

In closing his narrative with the end of the nineteenth century, the author is not able to give the final results of the silicosis problem. He intends to discuss these discoveries and controversies and those in the field of miners' nystagmus, anemia, and pulmonary neoplasm in a second volume, where he will also deal with the more recent American contributions to the study of miners' diseases. It would be most desirable if in this second volume he could also give some highlights on mining and miners' diseases in the Western Hemisphere during the pre-Columbian and colonial eras, for very interesting material from these earlier times also exists.

Occupational diseases are best suited to illustrate the social implications of disease and medical research. In writing the first monograph on an occupational disease in what is one of the oldest and basic industries, Rosen has done pioneer work and, as Sigerist states in his introduction, has "produced a captivating book that will be read and appreciated not only by physicians but by all those who are interested in the history of civilization and are concerned about the people's health."

MEDICAL CARE OF THE DISCHARGED HOSPITAL PATIENT.

By Frode Jensen, H. G. Weiskotten, and Margaret A. Thomas. The Commonwealth Fund, New York. $1.00. 8½ x 5½; 94; 1944.

This is the story of a successful experiment in extending the range of a hospital's service, improving the care of chronically ill patients, and relieving congestion in the medical wards. The study was undertaken by the Syracuse University College of Medicine after a preliminary survey had revealed that 90 per cent of the cost of service in the general medical wards at the University Hospital was for chronic illness, and that only a third of these patients were receiving satisfactory medical supervision after discharge.

With the cooperation of various health, medical, and welfare services in Syracuse, a program was set up which affected all patients discharged from the medical wards in more than one and a half years. The University Hospital appointed an extramural resident to familiarize himself with the medical aspects of these cases and relevant emotional, social, and economic factors, and to continue the medical supervision of the patients in their homes after discharge.

It was soon discovered that, because of proper care in the home, many patients could be discharged earlier, and rehospitalization was greatly reduced. The saving in hospital costs was about three times the cost of the experiment, or, viewed in another light, sufficient hospital facilities were released to permit the acceptance of several hundred additional patients. Of even greater importance was the better medical care received by the patients.

This challenging experience is of interest to hospital administrators, physicians, health officers, welfare leaders, and all others concerned with community

health. It deserves a wide and careful reading. There is a bibliography, but no index is provided.

THE FIRST WOMAN DOCTOR: *The Story of Elizabeth Blackwell, M.D.*

By Rachel Baker. Julian Messner, Inc., New York. $2.50. 9 x 6¼; 246; 1944.

This is an intensely interesting account of the life of a most remarkable woman, a pioneer in every sense of the word. Elizabeth Blackwell was born in Bristol, England, in 1821, the daughter of a prominent sugar refiner, himself an ardent reformer. When Elizabeth was eleven years old the family emigrated to America. A series of circumstances led her in her early twenties to make up her mind to become a physician. Calmly and courageously she applied for admission to medical school—only to be turned down for the simple reason that she was a woman. "There has never been a woman student in our school," the famous Dr. Samuel Jackson, chairman of the Institutes at the University (Philadelphia) told Elizabeth in reply to her request, "nor at any other institution of medical instruction in the States. In fact, I know of no country, madam, in which such a request has been made—or granted." This was in the year 1847. Finally, when all hope had vanished and only a feeling of stubbornness held her up, a letter came from a small, unimportant school, the General Medical College (later known as Hobart College) located in Geneva, New York, granting her permission to enroll as a medical student. The winter lectures had already begun! The strange reception she received at the school puzzled and depressed her. (She did not for a long time find out that her acceptance was entirely the result of a joke and an accident!) Although the going was hard, she finally won the admiration and respect of the entire faculty and student body. On the 1849 roster of students her name was posted as a graduate.

Three months later Elizabeth Blackwell left for Paris with the hope of being admitted as a post-graduate student in surgery at one of the better Parisian hospitals. Everywhere she was refused admission. After a month of this treatment, she decided to enter the big woman's hospital, La Maternité, as a common nursing apprentice. By so doing she could at least, she convinced herself, see the inside of one of these great institutions before returning to America. Needless to say, it was not long before her talents were discovered by the chief physicians, but just as her ambitions were about to be realized an unfortunate accident occurred that impaired her eyesight and destroyed forever her hope of becoming a surgeon.

From Paris she went to London, whence a cordial invitation had come from St. Bartholomew's Hospital. The famous Professor James Paget himself assured her that she would be welcome as a graduate student. The ticket of admission was enclosed. In England she was greeted like a heroine and here made many very interesting friendships.

Elizabeth returned to America in 1851. To establish a college for women was her dream. But even more important was a hospital in which women students might practise, and if not a hospital, at least a dispensary. Through a series of talks, entitled "The Laws of Life with Special Reference to the Physical Education of Girls," she succeeded in interesting a few prominent and charitable-minded women whose aid resulted in the opening of "The New York Dispensary for Indigent Women and Children" in one of the worst neighborhoods of the city. Her circle of friends was larger, and there were now people who believed in her. Yet even her most ardent and enthusiastic friends could not agree when she began talking of a new project: a woman's hospital to be run by a staff of women physicians! If anything, criticism made her more determined, and in 1857 the New York Infirmary for Women and Children was opened. Dr. Henry Ward Beecher was the speaker. By the end of the first year a course for training nurses scientifically had been inaugurated—the first school of nursing in America. A little later an "out-patient service" was added—an ambitious plan and entirely new. In 1864 the New York State Legislature voted an enabling act for a woman's medical college. Two years later, with an enrollment of fifteen students, the new school opened. The course was to be of four years' extent, as Elizabeth had planned. All instruction was to be personal. And for the first time in the history of American medicine the subject of disease prevention was taught. Elizabeth occupied the chair of hygiene.

The school grew rapidly, and so did the recognition of women in the profession of medicine. Celebrating the twentieth anniversary of her graduation, Elizabeth Blackwell could well declare, "The pioneer work in America is ended."

PRACTICAL MALARIA CONTROL: *A Handbook for Field Workers.*

By Carl E. N. Gunther. Foreword by Harvey Sutton. Philosophical Library, New York. $2.50. 8 x 5½; 91; 1944.

In this short and rather dogmatic treatise the author has outlined the main problems in malaria control and summarized the principal approaches to the handling of these problems. Since the author has had a decade's experience with the problem of malaria, one cannot help but wish that he had cited his experiences as direct examples of the problems and the methods of handling them. The book would have offered more fascinating

reading with such an approach than it does in its rather didactic, and in some cases misleading, present approach. The book is well written, in an easy style, and is well worth reading as the testimony and conclusions of a man who has faced and battled the malaria problem in New Guinea.

TROPICAL NURSING: *A Handbook for Nurses and Others Going Abroad. Second Edition.*

By A. L. Gregg. Philosophical Library, New York. $3.00. 6½ x 5½; x + 185; 1944.

While written primarily with the nurse in mind, this book is designed to familiarize both nurse and layman with medical and health problems in the tropics and to prepare such people for the care of themselves and others when more or less removed from the services of a physician. The book is divided into five sections, as follows: I, Personal Hygiene; II, Diseases; III, Technique; IV, Care of the Eyes; and V, Glossary. The first section is particularly well executed, in that it takes up the problems of the nurse's own health and welfare in the tropics as a pattern for all immigrants in those areas. In the second section the diseases are taken up in alphabetical order, and stress is put upon the etiological agent, clinical course, diagnostics, signs and symptoms (including laboratory aids to diagnosis), nursing care, and specific therapy of each. While this is well done, on the whole, there are many signs that this second edition is not wholly up to date. Scientific names of etiological agents are frequently obsolete, and while this is not too important, it raises doubts in the mind of the informed. Worse, the therapeutic suggestions are in some cases more than a decade behind the times, viz., the listing of santonin and oil of chenopodium as the first and second drugs for ascaris, and the failure even to mention tetrachlorethylene for the treatment of hookworm. With the known shortage of quinine, it seems undesirable to stress the use of this drug for malaria while failing to outline more fully the distinct advantages of atebrin (mepacrine). The reviewer was also disappointed in the fact that specific preventative procedures were often passed over with casual mention or with such very general suggestions as sanitation as one of the means of protecting against beriberi. The third section (Techniques) gives many practical suggestions, ranging from nursing care to technical procedures in the laboratory diagnosis of infections. The section on the Care of the Eyes (IV) is general and brief but effective. Despite the criticisms that have been made, particularly that the latest information has not always been utilized, the book is likely to prove very valuable to the nurse or layman about to venture into the tropics. It is readable and will serve as a handy reference.

INTRAVENOUS ANESTHESIA.

By R. Charles Adams. Paul B. Hoeber, Inc., New York and London. $12.00. 9½ x 6½; xiv + 663; 1944.

This unique monograph represents a distinct advance in the literature of anesthesiology. The subject matter treats of one phase of a medical specialty and does it with thoroughness and authority.

The book contains twenty-eight chapters, the division of which is based upon the anesthetic agent discussed. Following a historical introduction, general considerations of the art of intravenous anesthesia and technics, the chapters are titled by the specific drug discussed. Thus, beginning with chloral hydrate, various chapters treat of such drugs as ether, paraldehyde, individual barbiturates and analeptics. The final chapter discusses the military aspects of intravenous anesthesia.

The treatment of each drug or agent in its specific chapter is uniform throughout the text. Chapters open with a brief historical sketch; the chemistry of the compound follows; and then come the pharmacology, dosage, clinical applications, and minor considerations such as incompatibilities, untoward effects, and antagonists. References are numerous.

The style of the author is attractive. Clinical cases are cited, and the author's own experience with various agents adds much interest to the text. The book appears to be quite free from typographical errors. On occasion, as in the description of ethyl alcohol and the pharmacology of ether, the author's statements are not fully in accord with acceptable medical knowledge.

The chapters on the barbiturates, and especially pentothal sodium, are highly commendable and warrant careful study by clinician and anesthetist. The review of these barbituric acid derivatives in one place is a very valuable contribution to the pharmacologic literature.

In the opinion of the reviewer, Adams has fulfilled his purpose as set forth in the preface. He has produced a volume that will serve as a ready reference work in the field of intravenous anesthesiology.

A TEXTBOOK OF PATHOLOGY. *Fifth Edition, enlarged and thoroughly revised.*

Edited by E. T. Bell. Lea and Febiger, Philadelphia. $9.50. 9½ x 6½; 862; 1944.

This textbook of pathology is dedicated to the student of clinical medicine and should serve admirably in this capacity.

The contents of this book are divided into general and specific pathology. In the first half, the material is treated from the point of view of etiology and is therefore a composite picture of all the pathological

processes that occur from any single cause; the special pathology, however, consists of isolated pathological changes peculiar to specific tissues. Whereas this format is usually disadvantageous to the student of pathology because of lack of unity, in this particular presentation many of the individual subjects are so thoroughly treated that little confusion results from the subdivision of material.

The last part of the book, dealing with special pathology, as is usual in this method of presentation, fails to provide a complete pathological picture. For instance, the pathology of the various types of pneumonia is well described under diseases of the respiratory system, but is not correlated with other tissue changes that occur in these infections, nor with the possible general sequelae. Similarly, although the specific pathology of subacute bacterial endocarditis is well presented under diseases of the heart, streptococcus infections, and blood diseases, to the reviewer there is a lack of perspective from this division of material. A final similar instance is the failure to present a composite picture of heart failure. Isolated lesions due to heart failure can be ferreted out in separate chapters, but there is no coherent picture of this important condition that is presented as a unity.

On the other hand, many subjects are complete and form an unusually good reference source. Tumors are well presented; treatment of the blood diseases is excellent; discussions of infections, viruses, and mycoses are quite complete. Recent information on shock, mechanical injuries, vitamin deficiencies and other subjects often neglected by the pathologist are included in this text. True, there are several dogmatic conclusions on controversial subjects, such as the origin of the macrophage and the etiology of rheumatic fever, endocarditis, and glomerulonephritis, but that is an author's privilege.

The excellent bibliography should be especially valuable to the clinician desiring recent information on pathological subjects. Not only is it complete, but there is an explanatory note after each reference, describing its subject matter. Illustrations are also excellent.

In summary, this is an up-to-date text book of pathology, which, although of little interest to the general biologist, should find wide use in the field to which it is dedicated by its author.

GERIATRIC MEDICINE. *Diagnosis and Management of Disease in the Aging and in the Aged.*

Edited by Edward H. Stieglitz. W. B. Saunders Company, Philadelphia and London. $10.00. 9¼ x 6; xix + 887; 1943.

Aging is a continuous process, beginning at conception and ending only at death. It is a process which we can describe in its symptoms, but not as yet explain. Aging has been defined as the change introduced by the factor of time in living. The involutional changes in advanced age can be regarded either as the consequences of the wear and tear of existence, or else as due to the diminution and cessation of function. The rate of aging can differ enormously in the various organs and varies widely in individuals.

The profound relation of age to health and disease has been most fully appreciated by pediatricians. That the gradual age changes in elderly and old people are also the special concern of medicine has not been adequately realized until quite recently, though the term "geriatrics" had been introduced in 1909 to designate that phase of medicine which concentrates on the health problems of the aging and the aged. In the present stage of our knowledge it is still impossible to distinguish everywhere between the changes due to normal senescence or senility and those caused by disease. Hence this treatise on geriatric medicine is not limited to strictly medical problems, but includes much that belongs properly to the broader field of gerontology, or the biological science of aging.

In this pioneering textbook a group of fifty-four distinguished authors have collected the most significant information concerning the medical problems of old age, which comprises "later maturity," beginning at 45 (±5) years, senescence, and senility. The forty-six chapters are grouped in sections dealing with "general considerations" (anatomic, physiologic, and mental age changes; principles of pharmacology, physical therapy, surgery, and anesthesia in the aged; medico-legal aspects of senility, etc.), specific systemic infective diseases, disorders of metabolism, of the mind and nervous system, of the circulatory system, of the alimentary system, of the skeletal system, of the blood, and of the cutaneous system.

It is a curious fact that all this knowledge has not been systematically collected until now, and that medicine has made enormous efforts to prolong life without corresponding organized interest in the best possible medical care of the steadily increasing number of people past their prime. In 1900 only 17 per cent of the American population exceeded 45 years of age. In 1940 this had increased to 26 per cent, and it appears that this ratio will continue to rise. In the future the medical profession will be called upon to treat more and more cases of cardiovascular renal diseases, of cancer, diabetes, fractures of the hip, senile psychoses, and other ailments specially common in old age. By aiming to prevent or postpone these causes of premature infirmity, geriatrics will add breadth and depth, rather than mere length, to life.

The present volume supplies a splendid and much needed foundation for future work on the many biological and clinical problems peculiar to old age.

PSYCHOLOGY AND BEHAVIOR

A Dynamic Era of Court Psychiatry 1914–1944. *Edited by Agnes A. Sharp. The Psychiatric Institute of the Municipal Court of Chicago, Chicago.* Free (paper). 9 x 6; 149; 1944.

This is a presentation of the staff of the Psychiatric Institute of the Municipal Court of Chicago, recording the first thirty years of the service of the Institute, presenting numerous current problems, offering some predictions about the future, and appealing for enlargement of the Institute's services. The history of the psychiatric work in connection with the court in Chicago goes back to the influence of Mrs. W. F. Dummer, who had such a big hand in the establishment of the Juvenile Psychopathic Institute and the selection of Dr. William Healy as its first director.

The Institute acts in an advisory capacity to the Municipal Court and of course handles an enormous amount of material in the course of a year, mostly in the diagnostic phase. There appears to be the same status of chronic understaffing and inadequate appropriation at this Institute as in other psychiatric establishments in close relationship with courts. At the same time, as in other instances, marked enthusiasm is present in the staff and in the members of the court themselves, and one may say that more than a beginning has been made in the closer cooperation of the law and psychiatry.

This book is a record of the actual work of the Institute and a source of interesting, factual material.

Language and Thought in Schizophrenia: *Collected Papers Presented at the Meeting of the American Psychiatric Association, May 12, 1939, Chicago, Illinois, and Brought Up to Date. Edited by J. S. Kasanin, with a preface by Nolan D. C. Lewis. University of California Press, Berkeley and Los Angeles.* $2.00. 8 x 5½; xiv + 133; 1944.

This is a volume of collected papers that were presented at the meetings of the American Psychiatric Association in May, 1939, and have been brought up to date, with comments by the editor, Dr. J. S. Kasanin. Most of the writers who have made significant and modern contributions toward the subject of language and thought in schizophrenia are represented: for example, Kasanin (and E. Hanfmann), Harry Stack Sullivan, Kurt Goldstein, Norman Cameron, John D. Benjamin, S. J. Beck, E. von Domarus, and Andras Angyal. It may be seen from the list of writers that the subject is approached from numerous standpoints—psychoanalytic, experimental, Rorschach testing, application of specific laws of logic and methodological approaches, etc. While the authors in general agree on the characterization of language and thought process in schizophrenic states, nobody yet has any well-founded theories which bridge the gap between the well-known or suspected dynamic factors in schizophrenia and the actual observable disorders in the thinking and language process. To bridge such a gap will demand the fullest exploitation of all available theories and methods, and perhaps of as yet undreamed-of conceptions. The most profitable development in the field is likely to be found in the functions of reality testing in the pre-schizophrenic child. One may suspect that a well-planned research into that field will make all the contributions contained in this volume appear as nibblings at the base of a mountain, and this is said in no depreciation of the excellent material here. At least these papers will throw light on what things have proven valuable to date in the examination of schizophrenic disturbances of language and thought, and they may offer suggestions for use in the further development of the topic.

Sexual Anomalies and Perversions. *Physical and Psychological Development and Treatment. A Summary of the Works of the Late Prof. Dr. Magnus Hirschfeld, Compiled by his Pupils. Emerson Books, Inc., New York; Francis Aldor, Ltd., London.* $4.95. 9 x 6; 630; 1944.

This is a summary of the works of the former president of the World League for Sexual Reform and Director of the Institute of Sexual Science in Berlin, compiled by his pupils. The book is divided into four parts, the first part dealing with normal development of sexuality, the second with irregular sexual development and quantitative irregularities, the third with deflections of the sexual impulse, and the fourth with sexual aberrations arising from fixations on component impulses. The book is a presentation of generally accepted material concerning these various fields, with a tendency to combine psychoanalytic interpretation with hormonal physiological teaching. In the book are numerous short case records illustrating all types of sexual abnormalities, with some theories concerning their origin and sketchy material concerning treatment. As an over-all handbook in which one might find illustrative case material, the volume is adequate, but it is somewhat difficult for this reviewer to see exactly how much a serious student of treatment can gain from it. As a publicist and crusader for a humane and enlightened attitude toward sexual difficulties, Hirschfeld no doubt has played an important part. It may be doubted that this book contains anything near an adequate presentation of the treatment methods that were developed in the Berlin Institute. As a reference book for students, psychologists, criminologists, probation officers, judges, and educationists it may be recommended. In this respect it will probably fulfil its purpose.

NEW GOALS FOR OLD AGE.

Edited by George Lawton. Columbia University Press, New York. $2.75. 9¼ x 6½; ix + 210; 1943.

This is a series of sixteen articles, by about as many authors, on the subject of old age. They were papers delivered originally in a course, "Mental Health in Old Age," conducted during the year 1940–1941 under the auspices of the Section on the Care of the Aged, of the Welfare Council of New York City, for superintendents and staff members of old age homes and for social workers. A few titles will indicate in some measure the scope of the book. Lawson G. Lowrey writes on "Adjustment Over the Life Span"; George Lawton on "Aging Mental Abilities and Their Preservation"; the late Lewellys F. Barker on "Physical Changes in Old Age and Their Effects Upon Mental Attitudes"; Nolan D. C. Lewis on "Applying Mental Health Principles to the Problems of the Aging"; Edward T. Hall on "The Creative Urge in Older People"; Helen Hardy Brunot on "Old Age at the Crossroads. Patterns of Living: In an Institution"; and Ruth Hill on "Old Age at the Crossroads. Patterns of Living: In the Community." There is an extensive bibliography concerning the problems of old age.

This is an excellent volume, well presented by the various authors, and throughout there is a humane spirit and a call to society for adequate recognition of the fact that there is an increasing number of old people in our midst, and that in this group we possess a treasure of assets that have been all too readily disregarded in late years. The reviewer found the personal note in Lewellys F. Barker's chapter most inspiring. If there was ever a man more successful at the business of growing old, this reviewer has not met him. Some of Dr. Barker's recipes would no doubt be generally applicable.

HUMAN BIOLOGY

THE THREE AGES: *An Essay on Archaeological Method. By Glyn E. Daniel. The University Press, Cambridge; The Macmillan Company, New York.* 85 cents. 7¼ x 4¾; 60; 1944.

To every science there comes a time when it is profitable to reexamine the old accepted concepts that form its foundation. In archeology, it has been one hundred years since Christian Jürgensen Thomsen laid "the cornerstone of modern archaeology" by dividing human prehistory into the three ages—the Stone, the Bronze, and the Iron. The elaboration of this simple system has proceeded to subdivision upon subdivision. In this brief essay the author points out that the three ages are three technological stages, applicable strictly only to Europe, the Near East, and large parts of Asia. Use of the three ages to designate archeological types and their associations is illogical and confusing, since, for example, "Neolithic axes are not restricted to Neolithic stages." The study of cultures is frequently reduced to an attempt to force them into some particular division and subdivision of the system, whereas actually different cultures may coexist in one region and frequently overlap the divisions of the three-age system. Neither is the three-age system intrinsically chronological, nor yet do its divisions coincide with those of food-gathering and food-producing or other functional-economic periods.

With logic and clarity Daniel urges that slavish adherence to this system be abandoned, lest it "become a millstone hanging around the necks of future archaeologists."

THE FORT ANCIENT ASPECT: *Its Cultural and Chronological Position in Mississippi Valley Archaeology. By James Bennett Griffin. University of Michigan Press, Ann Arbor.* $6.00. 10½ x 7½; xv + 392 + 157 plates; 1943.

The archeology of the northeast United States, which was written off by the archeologists of the last century as finished, has within the last fifteen years undergone a strong revival. New techniques, vastly greater attention to detail, more accurate and more extensive excavation, and a more mature science of anthropology have demonstrated that the simple picture originally conceived is far from complete.

The Fort Ancient Aspect, one of the major archeological divisions of the Ohio River, is placed within the major framework of the Eastern American archeology. The discussion concentrates on defining this culture, and attempting to show its relationships to the historic tribes of the area and to the archeologic cultures of the surrounding areas. An opening section discussing the association of historic tribes with the Fort Ancient area is accompanied by reproductions of early historic maps of the areas, and shows the author to be a master of the history of the region as well as of its archeology.

This monumental work, which to judge by its sheer bulk should dispose of all of the problems of the area, serves largely but to clear the ground and state clearly the major problems that are still to be solved. The great size of the work is due to the author's exemplary effort to present his evidence objectively and in great detail. Speculation and theory is kept at a minimum. It is largely the work of a specialist and for the specialist.

YALE UNIVERSITY PUBLICATIONS IN ANTHROPOLOGY. *Number 27. An Archeological Survey of Venezuela,* by Cornelius Osgood and George D. Howard. *Number 28. Excavations at Ronquin, Venezuela,* by George D.

Howard. *Number 29. Excavations at Tocoron, Venezuela*, by Cornelius Osgood.

Yale University Press, New Haven; Oxford University Press, London. $3.50 (paper). 9¼ x 7; No. 27, 153 + 15 plates; No. 28, 90 + 7 plates; No. 29, 72 + 16 plates; 1943.

Venezuela is important archeologically, so this author tells us, because it lies transversely across both paths by which early man entered South America from his place of origin in the Old World. One of these paths, the obvious one, was by way of Middle America and the Isthmus of Panama, while the less conspicuous route was by way of Florida and the Antilles. If these early migrants had achieved civilization before they arrived at the point of divarication of the two routes, and if their subsequent progress was sufficiently slow, we might reasonably expect to find evidences of two cultures in Venezuela, in the east and the west respectively, and overlapping in the middle. As a matter of fact this is exactly what we do find, but we are not justified in jumping hastily at conclusions. In the first place, it is most unlikely that these aboriginal immigrants had developed any civilization at all before they had penetrated to the Peruvian Andes, far south of Venezuela, and in the second place, at the point where the two Venezuelan cultures overlap that of the lower horizon is the more highly developed. The correct explanation of the two Venezuelan cultures appears to lie in comparatively recent migrations within the Orinoco valley, and in a cultural degeneracy of the natives.

The civilizations of the Old World developed along the rivers—the Nile, the Euphrates, the Indus, the Hwang Ho. Their periodic inundations renewed the fertility of the soil, and communication was easier along the profile of equilibrium. But the civilization of the New World developed away from the rivers, and generally west of the Cordilleras despite the fact that with few exceptions the great rivers of the Americas all flow eastward. Perhaps this can be accounted for partly by the presence of malaria along the Atlantic seaboard, partly by the occurrence of the llama and maize corn only in the Andean highlands, and partly by the fact that the immigrants came from eastern Asia. In any case, however, the eastern American cultures were primitive without being primeval, and that of the Orinoco valley was no exception. For this reason the various sites discussed in this volume have received less attention from general archeologists than the more spectacular regions of Peru and Mexico, and much less is known about them. History is not very helpful either, for Venezuela had no Ramirez or Ixtlilxochitl to commit to writing the traditions of the pre-Columbian inhabitants.

The volume here under consideration is a chronicle of three expeditions into Venezuela. It is a scholarly compilation of data, so highly technical that it is not likely to excite any enthusiasm in readers not already interested in the subject. However, it is well written, and contains discussions of the history, topography, flora, and fauna of the region explored, and is well illustrated with both drawings and photographs of the sites investigated, the artifacts found there, and cross sections of the stratigraphy, as well as with maps and tables. Unfortunately there is no index.

This survey is one of ten projects covering the greater part of Latin America which have been apportioned to various universities in both the Americas.

ARCHEOLOGICAL EXPLORATIONS IN THE CORDILLERA VILCABAMBA SOUTHEASTERN PERU. *Viking Fund Publications in Anthropology Number Three.*

By Paul Fejos. The Viking Fund, New York. $3.50 (paper). 10 x 7; 75 + 80 plates; 1944.

In 1940–1941 an expedition, led by Dr. Fejos and financed by Dr. Wennergren (who also finances this excellent series of Viking Fund Publications, edited by Prof. Cornelius Osgood of Yale), located, cleared, mapped, and photographed six major Inca ruin sites, south of the famous Machu Picchu and about 45 miles northwest of Cuzco. The exploration was somewhat of an improvisation, and therefore no excavations were undertaken. This limits the possible results, which nevertheless remain very valuable.

The sites point to a dense population in the past. A prominent feature of most sites is the water system (drainage from rooms and terraces; baths; reservoirs and fountains). The communication system in and between the sites is very well developed (road tunnel between Phuyu Pata Marka and Sayac Marka). None of the sites seems to have been built with a view toward defense.

Text, maps, and plates are equally excellent.

ANTHROPOLOGICAL PAPERS. *Smithsonian Institution, Bureau of American Ethnology Bulletin 133, Nos. 19–26. A Search for Songs Among the Chitimacha Indians in Louisiana*, by Frances Densmore; *Archeological Survey on the Northern Northwest Coast*, by Philip Drucker with Appendix; *Early Vertebrate Fauna of the British Columbia Coast*, by Edna M. Fisher; *Some Notes on a Few Sites in Beaufort County, South Carolina*, by Regina Flannery; *An Analysis and Interpretation of the Ceramic Remains from Two Sites near Beaufort, South Carolina*, by James B. Griffin; *The Eastern Cherokees*, by William Harlen Gilbert, Jr.; *Aconite Poison Whaling in Asia and America, An Aleutian Transfer to the New World*, by Robert F. Heizer; *The Carrier Indians of the Bulkley River—Their Social and Religious Life*, by Diamond Jenness; *The Quipu and Peruvian Civilization*, by John R. Swanton.

United States Government Printing Office, Washington, D. C. $1.00 (paper). 9¼ x 5½; ix + 615 + 34 plates and 2 maps; 1943.

It is impossible to discuss here every one of the eight papers, though every one would merit discussion because of its high quality. The reviewer can only signalize a few items that seem to merit special attention.

Drucker's survey of northern northwestern archeology, though not yet presenting definite results, is a first and very substantial attempt to fill one of the most surprising gaps in American archeology.

Gilbert's 250-page monograph on the social system of the Eastern Cherokee is one of the most important contributions to North American anthropology published during the last few years. A detailed description of the present social organization, most successfully analysed from a functional point of view, reveals a system of preferential mating that in its peculiarities can be duplicated among described tribes only in Australia. Careful search in numerous manuscripts of the Ayer Collection of the Newberry Library, Chicago, has enabled the author to give us an excellent picture of the vanished dual social organization of the past. The relative importance of such historical data for understanding the present-day social organization is most intelligently discussed.

Heizer has gathered valuable data, equally important because of the interest of the whaling technique itself and because of the diffusionist implications of the data.

Jenness' report on the Carrier Indians, besides including interesting material on their sociology, contains descriptions of special mental diseases and their treatment among those Indians that are among the most important documents in this field ever published.

ETHNOGRAPHY OF THE YAGUA. *Viking Fund Publications in Anthropology. Number One.*

By Paul Fejos. The Viking Fund, New York. $3.50 (paper). 10 x 7; 144 + 56 plates; 1943.

These are the results of fieldwork done in 1940–1941. The Yagua live along the Marañon (Upper Amazonas) River in northeastern Peru, between the Rio Napo and Rio Jutahy, and number about 1000 individuals. Clans (25 to 50 members) live apart and inhabit a single community house. Hunting provides the staple food. After an excellent historico-geographical introduction, the author follows very much the classic scheme of description: technical culture, life cycle, social institutions, religion, etc. The only more modern feature is a chapter on "The Integration of Yagua Culture." There is nothing sensational either in the culture of this little tribe, which follows the typical patterns of tropical South America, or in the straightforward presentation of this monograph. But because of its wealth of interesting details and its solid craftmanship it will be most welcome to all those interested in anthropology, who rightly complain of the phenomenal lack of reliable material—especially in English—so far as South America, the stepchild of ethnography, is concerned. The illustrative material of the book deserves special praise.

UNIVERSITY OF CALIFORNIA PUBLICATIONS IN AMERICAN ARCHEOLOGY AND ETHNOLOGY. *Vol. 35, No. 10. Obervations on the Yurok: Childhood and World Image*, by Erik Homburger Erikson. *Vol. 39, No. 3. Concerning the Middle Chimu Style*, by Jorge C. Muelle. *Vol. 40, No. 1. Studies in Plains Indian Folklore*, by Robert H. Lowie. *Vol. 40, No. 2. Notes on Pomo Ethnogeography*, by Omer C. Stewart. *Vol. 40, No. 3. Washo-Northern Paiute Peyotism: A Study in Acculturation*, by Omer C. Stewart.

University of California Press, Berkeley and Los Angeles. Vol. 35, No. 10, 50 cents (paper). Vol. 39, No. 3, Vol. 40, Nos. 1 and 2, 35 cents (paper). Vol. 40, No. 3, $1.00 (paper). 10¼ x 6½. Vol. 35, No. 10, vi + 46; Vol. 39, No. 3, 20 + 2 plates; Vol. 40, No. 1, 28; No. 2, 34 + 1 map; No. 3, vi + 80 (2 plates). 1943.

Observations on the Yurok is one of the very few attempts to apply psychoanalytic methods to anthropological material that is worth reading and discussing, since the author has taken his clues from the actual material and not from holy dogma. The author explains the Yurok world image as a magic synthesis of experiences with the specific environment (salmon fishing in the Klamath River) and of experiences with the human body. Application of his findings to biographical material from a woman healer, to symbolical elements in house structure, to the Yurok creation myth, to the great fish-dam rite, show that the author's approach makes sense. He gives an excellent description of the methods by which the Yurok character is built up in early childhood. The least successful part of Dr. Erikson's otherwise enlightening and comprehensive contribution seems to me his discussion of oral versus anal traits. This is probably more important for his psychoanalytic brethren, who, I am afraid, will excommunicate him, than for the uninitiated reader.

The paper by Mr. Muelle explains very ingeniously the differences between early and late Chimú style arising from the influence of metal techniques on the pottery of the later period.

In *Studies in Plains' Indian Folklore*, the author compares different versions of the "Grandson Myth" among the Hidatsa and Crow. He discusses variations in a short Crow ritual and war story reproduced at different times by the same individual.

In *Notes on Pomo Ethnogeography*, the author

comes to the conclusion that Pomo linguistic and tribal boundaries cut across environmental provinces, and that similar special developments in property ownership and political organization appear, in spite of linguistic differences, where a favorable environment has made possible equally large populations.

In *Washo-Northern Paiute Peyotism*, the author has had the great privilege of observing a new religion (peyotism) in the making among the Washo and the Northern Paiute. After a most excellent description of the events and actors, he undertakes a painstaking quantitative and qualitative analysis of the process. He obtains the surprising result that neither the old "cultural compatibility" nor the "disintegration" theory can be maintained as explanations for the diffusion of the new religion. He cannot find any but individual reasons, differing with every individual; an important factor seems to be the personality of the "apostle," who is often motivated by economic goals. Dr. Stewart also discusses carefully older material on peyotism and the ghost dance from this angle. In this stage his explanation is, of course, highly unsatisfactory, as it actually denies every regularity in a fundamental social phenomenon; but it points to new ways and tasks of research and analysis. Thus the paper, quite apart from its fascinating contents, remains a most valuable contribution to social anthropology and the sociology of religion.

YOKUTS LANGUAGE OF CALIFORNIA. *Viking Fund Publications in Anthropology Number Two.*

By Stanley Newman. The Viking Fund, New York. $2.50 (paper). 10 x 7; 247; 1944.

The use of this excellent grammar of the Yokut language, a work written in the great tradition of Franz Boas and Edward Sapir, is, of course, restricted to a relatively limited number of specialists.

ANTHROPOLOGICAL PAPERS. *Smithsonian Institution, Bureau of American Ethnology Bulletin 136, Nos. 27–32. Music of the Indians of British Columbia*, by Frances Densmore; *Choctaw Music*, by Frances Densmore; *Some Ethnological Data Concerning One Hundred Yucatan Plants*, by Morris Steggerda; *A Description of Thirty Towns in Yucatan, Mexico*, by Morris Steggerda; *Some Western Shoshoni Myths*, by Julian H. Steward; *New Material from Acoma*, by Leslie A. White.

United States Government Printing Office, Washington, D. C. 75 cents (paper). 9¼ x 5¾; viii + 375 + 32 plates; 1943.

Densmore, who in forty years of untiring labor has collected a most impressive body of information on the music of the Indians of the United States, gives here for the first time data on Indians outside of the frontiers of the United States. As usual, her paper contains, besides purely musicological observation, a wealth of material on Indian culture, especially as to the treatment of disease.

Steggerda has established a connotated list of one hundred Yucatan plants not yet dealt with in the lists of Roys and Standley. In his second paper, he gives a short "Baedeker" of thirty present-day Yucatan towns. Steward has collected twenty-two Shoshoni myths; some have several variations. White publishes additional material to his well known monograph on the pueblo of Acoma. The most valuable part of this contribution is probably the autobiography of an Acoma Indian.

ASIA'S LANDS AND PEOPLES: *A Geography of One-third the Earth and Two-Thirds its People.*

By George B. Cressey. McGraw-Hill Book Company, Inc., New York and London. $4.50. 10¼ x 8; xi + 608; 1944.

The great importance of Asia and its peoples to other nations, in the war and after the war, makes such a book as this new geography by the author of *China's Geographic Foundations* indeed welcome. An enormous amount of painstaking labor has gone into the treatment of Asia's regions: China, Japan, the Soviet Union, Southwestern Asia, India, and Southeastern Asia. Many men intimately acquainted with these realms have contributed their knowledge. The fine photographic illustrations are supplemented by clear graphs of monthly rainfall and temperature at numerous points, and by maps drawn on one of three scales (1:75,000,000; 1:30,000,000; 1:2,000,000), so as to afford ready comparison. There are twenty-two pages of selected readings at the end of the volume, with valuable comments on the character of the references. The index is adequate.

The two introductory chapters deal respectively with the Pacific Basin, across which America faces the new Asia; and with Asia's continental patterns of topography, climate and vegetation, people, and regional divisions.

The seven chapters on China, perhaps because of the author's more intimate acquaintance with this land, are the best in the book, although the five on Japan and the seven on the Soviet Union are scarcely inferior. The decision to include all of the Soviet Union in the treatment, on the ground that no real boundary between Asia and Europe exists within the Soviet Realm, is particularly to be applauded. India might well have been given a more extensive treatment, in view of its rapidly increasing industrial importance, its enormous population, its great diversities of people, cultures, and land. Southeastern and Southwestern Asia are only briefly sketched.

The one adjective that best describes *Asia's Lands and Peoples* is *encyclopedic*. The scope of the treatment includes history, political divisions, population problems, communications, geological foundations, river patterns, surface configuration, climate, natural vegetation, soils, mineral resources, agriculture and land use, and regional descriptions. Apart from the always questionable statistics of Asiatic lands and an occasional minor slip such as the statement that in Japan the Bai-u rains of mid-June to mid-July are "plum blossom" rains, there are remarkably few errors. On page 427, the key to the map of India's flora is topsy-turvy. The reader should be prepared to supplement the maps in the book with a good atlas, as alone they are inadequate.

No one could find a better general introduction to Asia and its peoples than this most timely book affords.

PEOPLES OF INDIA. *Smithsonian Institution War Background Studies Number Eighteen. Publication 3767.*

By William H. Gilbert, Jr. Smithsonian Institution, City of Washington. 25 cents (paper). 9 x 6; 86; 1944.

The Smithsonian Institution has already printed a large series of booklets on those foreign countries with which the American at war may come in contact today. Knowledge of other peoples and their material and cultural background is a prerequisite for any satisfactory international cooperation. Yet just this aspect has been dangerously neglected in the educational schemes of all modern nations. Knowledge and real understanding of other nations and cultures must become one of the main goals of post-war education, not only of children, but also of adults. The "War Background Studies" of the Smithsonian Institution will help open the first breaches. It is clear that a pamphlet of 86 pages can hardly give more than a rather superficial picture of any country, especially one as complex in every regard as India.

This old and famous subcontinent and its peoples and traditions are today as nebulous, romantic, and distorted in the mind of most western peoples as they are prominent in newsprint and political discussions. If the present pamphlet, merely by pointing out the tremendous complexity of the ethnic, social, political, economic, and religious problems involved, succeeds in creating more caution, more reserve—and more patient study—in the approach to the Indian problem, it will have done a great service.

The short space and comprehensive scope of the pamphlet often allow only a very rudimentary discussion, and too frequently mere enumeration. This makes reading sometimes cumbersome. But a persevering reader will find an immense treasure of information on practically all aspects of Indian life. There are descriptions of the topography, geology, climate, vegetation, fauna, and natural resources. Then we find a presentation of the various cultures and races of the country, its history, government, languages, religions, and social organization. Finally, the all pervading caste organization and the innumerable castes are described at some length. The author stays aloof from taking sides throughout the discussion, which is always objective—almost cold. However, the reader who has mastered the basic information offered here may then add the warmth of sympathy and force of intelligent partisanship in the struggles taking place today.

The splendid photographs and several maps aid greatly in creating a concrete and vivid picture. There is a selected bibliography, but no index.

THE BLACK MAN'S BURDEN.

By John Burger. Victor Gollancz, Ltd., London. 7s. 6d. 7½ x 5; 252; 1943.

This is the story of South Africa. Yet, as the title suggests, it is also more. Its theme is familiar on all continents. Economic slavery, exploitation, and discrimination have been the faithful shadow of the growing industrial nations and have followed them everywhere on their conquest of the globe. Truly, we find today that within these nations freedom and justice are increasingly victorious. The "Four Freedoms" are the proclaimed goal of the United Nations. But the road is long and military victory over fascism only the beginning. The war has awakened freedom-loving people to the fact that liberty is indivisible, that suppression and injustice in one part of the earth endanger democracy everywhere. Only if it becomes world-minded can democracy survive. What has happened to the Bantu in South Africa, to the Pariah in India, the Jews in Poland, and the Negroes in the United States is the business of every man and woman everywhere. Therefore, the reading of books like the *Black Man's Burden* is a civic duty. The author, a South African writing under a pseudonym, has succeeded in putting an enormous amount of information on every aspect of life into a very readable form. Though the life of the colored population and the relationship between the various ethnic groups are in the foreground, one finds much about the general problems of the Union, cultural, economic, and political. Two chapters give the historical background up to 1940. Then we are introduced to the life of the Bantu in the reserves, where, in too small a space, an ignorant, superstitious, poverty-stricken peasantry is held as labor reserve. The taxes are high enough so that most men have to work at least part of the year in the mines. Tribal institutions are greatly impaired, without anything else taking their place. Outside of these reserves natives may not own any land. They provide

75 per cent of the laborers in the European rural areas, inadequately housed and fed. In the towns, most natives live in segregated "locations," which are mostly slum areas. Most natives in the towns work in mines and industry. Their wages are kept at the limit of subsistence by the labor surplus from the reserves. In short: "The vast bulk of the workers in South Africa live under conditions of overcrowding, underfeeding and the lack of essentials for even a low standard of living; they are, in fact, exploited to about the same degree as British labour was in the early days of the Industrial Revolution."

The government of the republics is elected by the people, i.e., with slight exceptions, the people of European descent. Colored people may vote in the Cape Province, but in the others they either do not have the right of suffrage, or complicated regulations make it practically impossible for them to vote. The Bantu in the Cape Province may poll in separate elections for three representatives of the 153 members of the House and four of the 44 senators. Members of the parliament must be of European descent and British subjects. Thus the more than seven million Bantu and Cape Colored are represented by seven members (who must be European) and the two million Europeans by 190 members. Not only politically, but in their entire lives the Natives are pinned down by color bars. They must always carry one or more passes, and on failure to produce them usually land in prison. Not only is their movement restricted, but labor laws also exclude them from most skilled work. Only very recently were colored unions recognized. In the execution of the law there is constant discrimination. Most vicious, however, is the color bar in education. There is one school for every 430 Europeans, one for 900 Colored and Asiatics and one for 1850 Africans. The state spends about seven times as much for a European schoolchild as for a non-European child. As in social welfare, the money for education of the native has to come from his own taxation. In general, public opinion is opposed to native education because schooling supposedly makes the native unfit for work, i.e., cheap work in European mines and industry. It is not astonishing that medical facilities are almost absent for natives, especially in rural areas. Native medical students have to study abroad, and but few find the means for that. It is no wonder that the native population provides dangerous centers for epidemics. This is aggravated by the generally poor nutrition. The parliament is dominated by the farmers. Thus the government subsidizes the agricultural products to be sold on the world market while the poor white and the native population live in chronic starvation. Of course they pay for that privilege with their own taxes.

The trade unions are as much interested in keeping and extending the color bar as the farmer or industrialist. They are afraid of native competition and are so far doing what they can to close all but the lowest paid jobs to native workers. These are poorly organized, and the difficulties in the way of unified action are almost unsurmountable. In the near future there is, therefore, very little hope for a decisive improvement in the native's situation. The politically powerful groups are all interested in keeping a great reservoir of cheap native labor, the nationalistic, conservative, race-conscious Afrikaner (descendent of the Boers) as well as the English-speaking capitalist and worker.

On the whole, we get the following picture of South Africa: It is a large and relatively poor country; economically it is dependent on the British stockholders and thus semi-colonial. The main political power is wielded by the British industrialists and financiers, the European workers, and the mostly farming Afrikaners. The basis for the whole economic structure is made up of the millions of segregated natives, who provide the cheap labor—a situation which differs from slavery only in minor details. The natives have practically no opportunity for education, very little medical attention, are undernourished, and live in rural or urban slums.

While the author gives an objective and comprehensive picture of the many factors shaping South Africa, his analysis of causes is less satisfactory. Being a Marxist, he overemphasizes economic factors, both as causes and as remedies. In this respect his presentation often appears superficial and oversimplified. But this in no way lowers the value of the book as a clear picture of the present situation.

Americans who might be prone to use this evidence to justify their criticism of British imperialism will, if honest and thoughtful, see a reflection of America's own treatment of her Negroes in this book. It is to be hoped that many Americans will read this book, and be instigated to more vigorous action at home. If so, John Burger will have done a great service not only to his own country but also to ours.

PLENTY OF PEOPLE. *Science for War and Peace Series. By Warren S. Thompson. The Jacques Cattell Press, Lancaster, Pennsylvania.* $2.50. 7¾ x 5¼; x + 246; 1944.

As crucial as any problem facing the world today,—inherent in the conditions alike of war and peace—is the problem of the growth of populations. In the Western world, nations are groping for means to stay the decline of population that threatens to bring economic disruption and national decline. In the East, on the other hand, failure of the birth rate to decline while the death rate is being rapidly reduced threatens to send populations soaring far above their means of subsistence; here the Malthusian dilemma is with mankind again.

The Director of the Scripps Foundation for Research in Population Problems has provided in *Plenty of People* a sound, readily intelligible discussion of the factors that influence population growth and decline, of the present trends in various nations, and of the social and economic consequences. In Chapter V the effects of war on population growth are discussed. Thompson differs emphatically with those who hold that war has no marked effect in this respect. Although he agrees that there is no convincing evidence that the quality of any people has been lowered by war (a point on which most geneticists will support him), and that war may not lead to any actual decline in numbers that is not easily regained, he points out that war has often led to a great deficit in numbers compared with the size the population would have attained at a given time had there been no war.

Nations are grouped according to their degree of control over their death and birth rates. The political and economic implications of the differential growth characterizing these groups become immediately forceful. The ultimate solution of population pressure must lie in the establishment everywhere of an equilibrium between these two rates. Today the centers of explosive force are being generated in those countries where the death rate is being steadily lowered but the birth rate remains uncontrolled. India, for example, appears to be faced with imminent disaster.

The relation of rural to urban population and the influence of migration are presented in excellent accounts. The effect of age changes particularly affects the United States. In what ways are we adjusting our social and economic pattern to the increasing proportion of older adults? The account of eugenics is sound but scarcely a well-rounded introduction, such as one can get from Frederick Osborn's *Preface to Eugenics*. The chapter on minorities is also very brief, although an amazing amount of information is packed into its seventeen pages. The book concludes with a very stimulating consideration of various population policies and the need for a well-planned population policy in the United States.

None of these subjects is treated with the graphic vigor one might expect from Stuart Chase; nor is there the thorough consideration of data to be found in the author's larger books. Nevertheless, it is to be hoped that every biologist and sociologist, every governmental official, and indeed every alert citizen will give this book the attention it deserves.

THE GOBI DESERT.

By Mildred Cable and Francesca French. The Macmillan Company, New York. $3.50. 8¼ x 6; 303; 1944.

Between northwestern China and the Russian Southeast and Siberia there lies a vast expanse of grasslands, sandy desert, mighty mountains, hidden springs, and isolated oases. This is the Gobi. Over its immemorial trade routes passed knowledge of wheel, saddle, and plow; silk, paper, and printing came to Europe and glass made its way to China; Greek influence, Buddhism, Nestorian Christianity, and Islam succeeded one another here. Five times the two authors, who in writing have merged themselves into a single personality, traversed its entire length of 2000 miles from the Pamirs to Shensi. Over a period of many years they travelled by cart from oasis to oasis, until everywhere from Yarkand and Kashgar to Urumchi, Hami, and Kiayükwan, the beginning of the desert, they were known and hailed as familiar friends.

There is bewitching beauty and fascination in this stark land, and in the way our travellers tell of it. There is poetry in the place-names: Jade Gate, River of Sands, Iris Well, One-Cup Spring, Bitter Well Halt, and Inexhaustible Spring. The authors tell of the sands and the black stones, the waters and the fierce winds, the heat and the desolating loneliness of deserted cities swallowed in the sands. They tell of the desert's wildlife: of the striking *Ovis poli* with its magnificent horns, and the wolves that pursue it; of the terns, the vultures, the Golden Eagles; of the yellow viper that hides in the cart ruts; and the agile jerboa that comes out at dusk to trail the caravan. They tell of the desert's plants, such as camel thorn, desert grass, saksaul, liquorice, and Ephedra. The descriptions of oasis crops spread a riot of color before the eye, and the luscious qualities and great variety of Tunhwang fruit, the wonderful melons of Hami, and the sultana raisins of Turfan fairly make the mouth water.

Yet after all it is the people of the desert oases who occupy the center of interest, and our authors know these people as well or better than any other white persons in the world. In the setting of wind and sand and parching heat, in the understanding of their historic religious and political rebellions and wars, in the light of their cultural differences from the time of the Han dynasty to the recent turbulent era of General Ma, Governor Yang, and Yolbas the Tiger Prince, we meet and come to know the Tungan, Turki, Chinese, Qazak, and Mongol merchants, carters, farmers, nomads, and priests, beggars, theatrical performers, and brigands. Quietly and with confidence that they bring the best of all gifts in their Christianity, these missionaries imbued with the true spirit of anthropologist and philosopher, respecting the age-old culture of central Asia and exchanging ideas with illiterate peasant woman and gentle Buddhist scholar alike, have learned to love, as they have learned to understand, the desert.

It would be an indignity to call this a travel book, it so far exceeds what that term usually signifies. But anyone who might wish to write of another land and other peoples could find no better model. There is true magic in these pages, the magic that comes

from the inner soul of the understanding wayfarer. It is magic that makes me, for one, eager to go myself to visit the Thousand Caves of the Buddhas, to sit beside the matchless sapphire of the Lake of the Crescent Moon, and to listen to the Singing Sands.

COMPENDIUM AND DESCRIPTION OF THE WEST INDIES. *Smithsonian Miscellaneous Collections Volume 102. Publication 3646.*

By Antonio Vázquez de Espinosa. Translated by Charles Upson Clark. Smithsonian Institution, City of Washington. $2.50 (paper). 9¼ x 6; xii + 862; 1942.

When Keats compared himself to an astronomer

"when a new planet swims into his ken,"

he was speaking the mind of every one who has ascended to the heights and gazed upon the undiscovered country lying beyond the horizon. Moses on Mt. Pisgah, Kino watching the sun rise over the Vermilion Sea, Champollion translating the Rosetta stone, Leeuwenhoek observing the protozoa through his homemade microscope—all these could understand the feelings of him who first penetrates the boundaries of human experience. And so could one Altimirano, who, as early as 1559, made the journey over the Andes and descended the Marañon to the Atlantic, accompanying the expedition led by the infamous and treacherous Lope de Aguirre, who, in order to bring himself luck carried a drum whose head was made from the tanned skin of a priest named Francisco Montesino, the said priest having been abducted and slain for this purpose by order of Aguirre himself. Altimirano's tale of the concatenation of assassinations perpetrated by Aguirre in order to perpetuate himself in power, and of Altimirano's own escape when he learned that he was slated to be the next victim, supplies enough blood and thunder to satisfy the most depraved devotee of soap opera.

The story of this adventure is incorporated in the narrative of Vásquez de Espinosa, who obtained it at first hand from Altimirano himself. Concerning Vásquez little is known beyond the fact that he was a barefoot Carmelite, who, after a life of evangelical endeavor in the Indies (which means all of Latin America as well as the Philippines), retired to Spain in 1622 and died there in 1630. During those last eight years he devoted himself to literary activity, his chief work being the *Compendium and Description of the West Indies*, now made available for the first time in English translation by Dr. Charles Upson Clark.

The manuscript of this magnum opus had been partly published anonymously, but was long considered a lost work. When Dr. Clark discovered it beneath the accumulated sands of time in the Vatican Library, there was no clue to the author. After much painstaking research the manuscript was finally identified, by Dr. Ernest Schafer, as the lost work of Vásquez de Espinosa, and Dr. Clark undertook its translation with renewed zeal. He was amply rewarded. For here is a complete contemporary description of the entire Spanish empire. The author begins his story with a dispersal of the sons of Shem after the deluge, to explain the origin of the American Indians on Biblical and apocryphal grounds. This is a strange mixture of superstition and scientific fact. If the reader regards the author's acceptance of the Tower of Babel narrative as factual history to be a trifle naive, let him consider the modernistic flavor of the same author's theory of continental drift, or his statement that when animals are introduced into a new environment they undergo structural modification, so that they no longer resemble their parents. This is strange doctrine to be promulgated by a contemporary of Giordano Bruno.

The author has given us a very graphic word picture of the ruins of Cuzco—that astonishing edifice that has excited the admiration and wonder of all who have ever seen it. Although the prehistoric inhabitants had no iron or steel, they were able to cut the building stones so accurately that it is difficult at first to see the planes of contact, and although they were unfamiliar with the use of wheels they succeeded in transporting blocks of stone over forty feet in length from one mountain to another. On one occasion, so he tells us, the cable by which the stone was being drawn parted, and the stone plunged down the mountainside into a group of Indians, killing three thousand of them instantaneously.

In some cases the author has indulged in hyperbole, as when he tells us that the condor measures sixteen feet across its outstretched wings, and that it lays an egg as large as that of the ostrich. But who would not be tempted to exaggerate after having seen a condor for the first time, in attempting to describe it to some one who had never seen one?

Again the author describes a tidal wave which he witnessed on the coast of Chile. The water of the sea, he tells us, withdrew from the land, and then in a single impulse it hurled itself on the shore, to obliterate completely the human habitations within a considerable area. The description may be exaggerated, but the destruction was not.

The author, being a Spaniard, naturally believes in the superiority of European civilization over that of ancient America, although he concedes that in at least one respect the Peruvians could not be surpassed. He believes them to have been the greatest road builders of antiquity (and those who have ridden over the section of Inca highway brought to Dearborn by Henry Ford are likely to understand why), and he blames the deterioration of the highways on the corruption and incompetency of the Spanish officials; also, being an ecclesiastic, he takes very seriously his

own duty to impose his particular brand of Christianity upon the natives. (Incidentally he refers to the English colonies between Florida and Cape Cod as heathen settlements). But he is not blind to the abuses frequently practised in the name of religion and does not hesitate to condemn them, whether they be committed by civil or ecclesiastical authorities.

We who live in what our neighbors south of the border call Saxon America are likely to be neglectful of the intellectual achievements of the Latin Americans. We remember that our first public library was in Philadelphia and our first printing press in Salem. But we forget that Mexico had a public library two centuries before Philadelphia and a printing press one century before Salem. We remember when Harvard University opened its doors, but one year before this event Vásquez de Espinosa was writing in his compendium about the Universities of Santo Domingo, Mexico, and Lima, and states that the citizens of Guatemala had petitioned for one of their own.

All told, this is a splendid book for the armchair explorer. Lost in its pages, the reader can accompany De Soto to the Mississippi, or Magellan to the Spice Islands. With Marcos de Niza he may search for the seven cities of Cibola, or with Francisco de Ulloa for the mythical waterway supposed to connect the Gulf of California with the Pacific near Cape Mendocino, making California an island. With Cortes he can live through the Noche Triste, or with Doña Beatriz de le Cueva he can witness the destruction of the Ciudad Vieja by earthquake and flood. He can explore the mysterious waters of Lake Titicaca in a balsa, or excavate the ruined cities of Coban, with their undeciphered hieroglyphics that, like the Columns of Sissa, testify to a vanished civilization.

CATALOG OF HUMAN CRANIA IN THE UNITED STATES NATIONAL MUSEUM COLLECTIONS: *Non-Eskimo People of the Northwest Coast, Alaska, and Siberia. No. 3171, from the Proceedings of the United States National Museum, Volume 94, pp. 1–172.*

By Ales Hrdlicka. The Smithsonian Institution, United States National Museum, Washington, D. C. Paper; 9¼ x 6; 172; 1944.

BIOCHEMISTRY

A SOURCE BOOK OF AGRICULTURAL CHEMISTRY. *Chronica Botanica, Volume 8, Number 1.*

By Charles A. Browne. The Chronica Botanica Company, Waltham, Massachusetts; G. E. Stechert and Company, New York. $5.00 (paper). 10½ x 7; x + 290; 1944.

Although primarily concerned with the background and developmental history of the application of the principles and interpretations of chemistry to the field of agriculture, this book has a wider usefulness as a source of background material in the whole field of biology.

The introduction, recognizing the inclusive and overlapping character of so broad and general a field, discusses its scope and objectives and its relation to other branches of science.

The seven main chapters of the book pursue in chronological order the development of agricultural chemistry up to 1850, from its theoretical and philosophical beginnings in early Greek and Roman times, successively through the periods of alchemy and iatrochemical theory, the beginnings of the Royal Society, the controversies of the phlogiston period, and finally the rapid advances that followed in the century from Lavoisier through Liebig.

Accessibility of the material is facilitated by a subject index of four and one-half pages and an author index of one and one-half pages, while an addendum of two pages furnishes any interested reader with a brief survey of the literature covering the advances in this field during the last century from Liebig to the present.

The thirty-two illustrations mostly display facsimile title-pages, tables, and text from classic publications or diagrams of historic apparatus and experimental procedures, giving the reader a scanty but very valuable idea of the form and character of early work.

Since the field is such a broad and inclusive one, and the development and functions of the plants and animals that are its living raw materials are the basis of biology, the book furnishes excellent collateral reading for students and investigators in botany, zoology, and physiology as well as in agriculture and chemistry.

The brief but effective accounts of some fifty-six historic figures, covering their work, experiments, interpretations and theories, and contributions to the progress and development of chemistry are of fundamental interest for the historic background they furnish. In each of these biographical sketches significant parts of the investigator's work are translated from the original, and each is supported by adequate references to the source literature.

In this book the reader will not only gain familiarity with the work and influence of some of the pioneers that have made history in various branches of science but will also note with interest the shrewd intuitive guesses, such as Democritus' atomic theory, that foreshadowed some of our modern concepts, finally established by adequate experiments hundreds of years later. Here he can learn of the persistence of theories such as the phlogiston theory, fallacious yet so seemingly plausible and so adaptable to new approaches that they survived for generations before finally being overthrown by more exact experimenta-

tion. Here he can trace the experimental method as the tool that has made progress possible in these as well as other branches of science.

Well chosen, well organized, and well presented, this book will prove a valuable source of material pertinent to many branches of science.

THE ALIPHATIC ALCOHOLS: THEIR TOXICITY AND POTENTIAL DANGERS IN RELATION TO THEIR CHEMICAL CONSTITUTION AND THEIR FATE IN METABOLISM. *Public Health Bulletin No. 281.*

By W. F. von Oettingen. U. S. Public Health Service, United States Government Printing Office, Washington. 35 cents (paper). 9¼ x 5¾; vii + 253; 1943.

This monograph represents an ambitious attempt to combine and summarize the available information regarding the general properties and toxicology of the aliphatic alcohols. Particular emphasis is placed upon information which might be of value in combating industrial hazards, and with that in mind the greater part of the volume is devoted to the monovalent alcohols, which are the most widely used and the most dangerous. The divalent alcohols are fully covered, but little space is devoted to polyvalent alcohols, since these have few of the toxicological properties of the monovalent alcohols and tend to resemble the non-toxic carbohydrates.

The various alcohols are discussed under the headings of chemical characteristics, uses, identification, determination, fate in the organism, toxicological properties, and suggested precautions and treatment. The pertinent literature has been exhaustively covered, and many references to work published before 1900 are included. In most cases the findings and conclusions of the original authors are merely presented as such, and little effort is devoted to analysing and evaluating the data.

An extensive bibliography and a good table of contents are included, but there is no index. This should be a valuable reference for those doing pharmacological work with alcohols as well as for those faced with toxicological problems arising from the industrial use of this group of compounds.

BIOMETRY

SIXTEENTH CENSUS OF THE UNITED STATES, 1940: VITAL STATISTICS RATES IN THE UNITED STATES 1900–1940.

By Forrest E. Linder and Robert E. Grove. United States Department of Commerce, Bureau of the Census, United States Government Printing Office, Washington. $1.75. 9¼ x 6½; vii + 1051; 1943.

The interrelated elements involved in the growth of a population present a fascinating study, and the volume under review offers a wealth of material for such study. Since 1790 we have found out every ten years how many people there were in the country. It was early recognized, however, that the subject of population was a dynamic one, not static, and that the census counts, although absolutely essential, needed to be supplemented by an entirely different type of information obtainable only through the recording of certain events, particularly births and deaths, when they occurred.

In 1900 the U. S. Death Registration Area was initiated, and starting with ten states and a few cities, the Area has gradually increased, until in 1931 it included the entire country. The Birth Registration Area was started in 1915 and covered the whole country in 1933. When the collection of these dynamic facts was begun, the Census Bureau started publishing annual volumes giving the number of births and deaths within the calendar year, tabulated for various important variables.

These annual tabulations take on added significance in census years, when the population base is most accurately known. Recognizing this, the Census Bureau published in connection with the 1920 census, a volume of "Mortality Rates 1910–1920." The present volume is the first comprehensive rate volume to appear since that time, and is particularly important because 1940 was the first census year in which the entire country was included in the Birth and Death Registration Areas. This volume is much broader in scope than the previous one, containing birth as well as death rates, subdividing the rates on more axes of classification, and of course covering a period which includes the entire history of the Federal registration system in this country.

The tables included in the volume are too extensive to describe in detail, but a general description will be attempted. The general mortality rates are given in twenty-five tables showing time changes in crude rates for the different states and in specific rates by age, race, sex, cause of death, and month. Infant mortality rates, maternal mortality rates, and stillbirth ratios are given in eighteen tables giving time changes by area, age, race, and cause of death. Natality rates, in nine tables, are shown by time, place, age of mother, race, and color. There are summary tables for the country as a whole and seventeen population tables.

The first 110 pages of the book are somewhat textbookish in character. They include chapters on the classification and tabulation of vital statistics data, the definition and interpretation of vital statistics rates, and adjusted death rates and other indices of mortality. Although it might be debated whether such material belongs in this type of publication, it will unquestionably be an aid to many users of the volume.

The authors state that some of the tables initially planned for inclusion had to be omitted because of the curtailment necessitated by the war. It always takes some time to find out what additional tables are in most frequent demand by the users. The book as it stands, however, fills a great need for those students of population engaged in analysing past history and estimating future trends of our birth and death rates and population growth. Such analyses are now recognized as essential in making an intelligent approach to programs for health, for education, and for other aspects of society's well-being.

TABLES PREPARED BY THE MATHEMATICAL TABLES PROJECT, *Works Progress Administration of the Federal Works Agency, under the Sponsorship of the National Bureau of Standards.*

The four volumes reviewed below are the 13th, 14th, 15th, and 16th volumes respectively in the excellent series of tables prepared by the Mathematical Tables Project. The project, initially under the Works Progress Administration, was discontinued by that Agency in March, 1943, and since then has been operated by the Bureau of Standards, which had sponsored the project from the outset. It is now supported by the Office of Scientific Research and Development, with the Applied Mathematics Panel of the National Defense Research Committee responsible for its program. This program is at present directed toward the preparation of tables useful for war activities, with the completion of tables started under the earlier administration as a subordinate part of the program. The tables reviewed in this issue are in the latter class.

Throughout the entire enterprise, the cooperation of leading scientists has been secured for every phase of the planning. An exceedingly valuable addition to our scientific equipment has been produced.

TABLE OF CIRCULAR AND HYPERBOLIC TANGENTS AND COTANGENTS FOR RADIAN ARGUMENTS. *Columbia University Press, New York.* $5.00. 10½ x 7¾. XXXVIII + 412. 1943.

The circular and hyperbolic tangents and cotangents are tabulated for radian arguments from 0 to 2 at intervals of 0.0001. Supplementary tables for the four functions cover the range from 0 to 10 at intervals of 0.1. At least eight significant figures of the functions are given. Tables giving interpolation coefficients for the Gregory-Newton formula and Everett's formula are also included to facilitate the attainment of interpolated values. There is also a table to convert radians into degrees, minutes, and seconds, and one giving multiples of $\frac{1}{\pi}$.

TABLE OF THE BESSEL FUNCTIONS $J_0(z)$ AND $J_1(z)$ FOR COMPLEX ARGUMENTS. *Columbia University Press, New York.* $5.00. 10½ x 7¾. XLIV + 406. 1943.

This volume tabulates for argument-points φ, ρ in polar coordinates, the real and imaginary parts, to ten decimals, of $J_0(\rho e^{i\varphi})$ and $J_1(\rho e^{i\varphi})$. The values of φ are given at 5° intervals from 0° to 90° and of ρ at intervals of 0.01 from 0 to 10.

A supplementary table gives 5-point Lagrangian interpolation coefficients to ten decimals for an argument ranging from 0 to 1 at intervals of 0.001. This table assists in evaluating the Bessel function at points not given in the main tables. The table is taken from a more extensive table of Lagrangian coefficients reviewed in this issue.

A useful foreword and introduction explain the nature of the Bessel functions and their scientific application, with a bibliography of sixty-six titles on the subject. Four graphs present contour lines of the functions.

The application of these functions is mainly in the solution of certain physical problems relating to vibrating membranes, heat conduction, and other problems in wave mechanics. In spite of the importance of the functions in this field, no comprehensive tables have heretofore existed.

TABLE OF RECIPROCALS OF THE INTEGERS FROM 100,000 THROUGH 200,009. *Columbia University Press, New York.* $4.00. 10½ x 7¾. VIII + 204. 1943.

This table gives reciprocals, to seven significant figures, of all the integers between 100,000 and 200,009. This range of the argument was chosen because in the tables available for the reciprocals of six digit numbers, the argument proceeds by such broad jumps in this range that a rather laborious interpolation is necessary to get the values at intermediate positions.

Probably for most biological problems the numbers involved are of such a size that Barlow's Table, which gives to seven significant figures the reciprocals of all integers from 1 to 12,500, is satisfactory, but for computation based on large numbers or in which a considerable number of figures needs to be carried in the course of the calculation the more extensive tables are of value.

TABLES OF LAGRANGIAN INTERPOLATION COEFFICIENTS. *Columbia University Press, New York.* $5.00. 10½ x 7¾. XXXVI + 394. 1944.

The problem of interpolating between tabled values of some function is very commonly solved by putting a polynomial through a certain number of the known values (the order of the polynomial being one less than the number of fixed values) and using the value of the polynomial at the desired intermediate point as an estimate of the function. If the argument is equally

spaced, the Lagrangian coefficients greatly facilitate the computation.

The present tables give interpolation coefficients for cases where the number of fixed points, n, is 3, 4, 5, ... 11. The argument differs for the different tables and will not be described in detail here. Included in the volume are also tables corresponding to the same values of n and giving Lagrangian integration polynomials and integration coefficients for determining values of definite integrals.

A very useful introduction shows a little of the theoretical background of the interpolation method and gives a number of arithmetical examples illustrating the use of the tables.

THE BULLETIN OF MATHEMATICAL BIOPHYSICS. *Volume 6, Number 4, December, 1944.*

Edited by N. Rashevsky. University of Chicago Press, Chicago.

This number contains the following papers: On the theory of blood-tissue exchanges: I. Applications, by R. E. Smith and M. F. Morales; On the theory of blood tissue exchanges: II. Circulation and inert-gas exchanges at the lung with special reference to saturation, by M. F. Morales and R. E. Smith; On the form and strength of trees: Part II. The primary branches, by I. Opatowski; The two-factor theory of nervous excitation with non-normal accommodation, by Alston S. Householder; Contributions to the mathematical biophysics of visual aesthetics, by N. Rashevsky and Virginia Brown.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

ANCIENT AND MEDIEVAL DYES.

By William F. Leggett. Chemical Publishing Company, Inc., Brooklyn. $2.25. 7¾ x 5¼; vi + 95; 1944.

There is hardly a people, however primitive, which has not developed some kind of art, which does not use some dye on its own body, on textiles or pottery, on baskets or on weapons. Plants and animals furnish a great number of dyes of many colors and only recently have these natural dyes been crowded out, after centuries of use, by the synthetic dyes of the chemist. *Ancient and Medieval Dyes* gives short and concise biographies of the natural dyestuffs that embellished man's handiwork for so many centuries, but which are almost forgotten today.

They have a venerable history, these dyestuffs extracted from plants, animals, or minerals. Their story is closely connected with the cultures of many peoples, and they played a great role not only in their artistic, social, and religious, but also in their economic relations. There is, for instance, the dye from the root of the madder plant, the *al sun* of the Arabs, *erythranon* of the Greeks, *rubia* of the Roman and *rote* of the German. Its history goes back as far as we have records of human civilization. Its cultivation was a complicated science in ancient times, then was forgotten during the Middle Ages and later was introduced again into Europe from Asia. Soon production of madder dyes grew into an important industry, above all in Holland and France, until the cheaper anilin dyes put an end to it. Today madder is cultivated in small quantities in a few countries for the use of artists, who still value the rich and deep colors of the Rubia root.

Not less interesting is the history of indigo, extracted from the leaf of a legume, *Indigofera tinctoria*. Before the discovery of the New World it was imported from India. Later, however, the West Indies and Central America became the most important sources of this blue dye.

The blue extract of the woad plant, cultivated in Europe, was for centuries the dominating blue, protected against competition from the foreign indigo by law in most European countries. Ultimately the finer quality of indigo won out, but its supremacy was quickly ended by the anilin dyes.

Famous yellow plant dyes are the saffron, the safflower and weld.

Of special interest to the biologist are the extracts of brazilwood and logwood (brazilin and hematoxylin), which are valuable histological and cytological dyes. Other less well-known dyes discussed are the barwood, camwood and fustics; orseille, the lichen extract; cudbear, annatto, tumeric, cutch, gambir, and quercitron.

Animals were not less important sources of dyes. The most highly priced dyestuff of ancient days was the Tyrian purple. It was the color of the kings of Media, of the royal houses of Persia, Babylon, and Syria, of Greek generals and Roman emperors. The source of this dye is a shellfish, Murex, and blue, red, or green colors were obtained from it.

A beautiful scarlet red was won from an oriental coccid, Kermes. It was probably discovered by the the Phoenicians and was the only insect dye known in ancient and medieval Europe. Kermes was displaced later by cochineal, the dyestuff from the Mexican *Coccus cacti*, which is a superior dye and more cheaply produced. Today it is entirely displaced by the azo dyes. Its product carmine, however, is still much used by the biologist.

Another coccid, *Coccus lacca* of Indo-China, Siam, and southern India, is the source of lac. This scarlet and crimson dye was known for centuries in Asia before it was introduced in Europe around 1800. Inferior to cochineal, it was never widely used.

Minerals also were found to dye textiles, e.g., iron salts, giving yellow, orange and brownish-red colors; malachite green; blue from azurite; and the yellow-brown and violet ochres. Most of these mineral dyes were first used by the Egyptians.

People of diverse interests will find this booklet useful, last but not least among them the biologist who is interested in the background of some of the histological dyes in his laboratory.

THE PACIFIC WORLD. *Its Vast Distances, its Lands and the Life upon Them, and its Peoples.*

Edited by Fairfield Osborn. W. W. Norton and Company, Inc., New York. $3.00. 9 x 6; 218; 1944.

Never before have American eyes been turned with so absorbing an interest upon the world of the Pacific. Our men in service there and their families and friends at home are equally eager to know more about its islands, peoples, climate, vegetation, and animal life. This handbook of the Pacific area was sponsored by the American Committee for International Wildlife Protection. The material has been gathered by no less than twenty-eight men of nine different educational and scientific institutions. The foreword is addressed to men of the services by William Beebe. There are seven colored plates showing the profile of Pacific depths and heights, its winds, ocean currents, migrations of peoples, mammals, birds, and butterflies and moths. There are regional maps and numerous figures, diagrams, and tables. The volume is convenient in size, and its style is simple and readable.

In spite of all this, the book is disappointing. This is largely due to the vast scope of the subject, no doubt. The first part of the book is general, in numerous places very general indeed. For example, there are two pages devoted to coral islands, reefs, and atolls; one to ocean currents; and one to tides. Chapter V, on "Stars over Melanesia," is complete in two pages plus a table of constellations and a double-page star-map of distorted and almost unrecognizable constellations, with directions for finding the zenith point that are self-contradictory. The seven-page chapter on the native peoples gives a little more information, but fails to explain why the accompanying color-plate surprisingly represents the principal migration into the Fiji Islands as one of Polynesians instead of Melanesians! The chapters on plants and animals include equally brief and general treatments of ocean life; mammals; birds; reptiles, amphibians, and insects; and plants. There is a brief survey of the gorgeous tropical butterflies and moths, but the mosquito is not even mentioned, nor is the distribution of malaria or other tropical diseases, whether carried by insect vectors or not, to be found in the volume.

The second part of the book consists of regional descriptions that are somewhat more detailed. That these were prepared by different authors than those who wrote the chapters of Part I is all too evident. Frequently the same items found in earlier chapters are repeated here, a misuse of space hardly excusable in a work so condensed as this must be. Nor is reference made where it should be. For example, in the colored plate of birds, in Part I, a bird identified as a megapode stands astride the Solomon Islands, but is not mentioned in the accompanying text. In Part II, the section on the Solomons tells of a "fowl, suggestive of a small turkey, that lays its very large eggs in piles of decaying vegetation," where they are incubated by the heat of the rotting plants. But this bird is not identified as the megapode. The index is no help, for "megapode" is not listed in it at all.

One will look in vain for any specific discussion of Tarawa, Makin, Truk, Saipan, or Kwajalein, although Marquesas and Tuamotus and other island groups far from war contacts are included. Haste has evidently produced errors, just as too many hands have resulted in a lack of integration. There are geographical errors of various sorts. Beri-beri is said to come from lack of vitamin A. Wages in Japan are compared on the basis of exchange rather than of purchasing power. The young tuatara has a vestigial third eye, readily seen under the skin, "a characteristic common to many lizards."

In the tables of distribution of mammals, birds, and reptiles and amphibians, only families or large groups designated by common names are listed. The service man who wants to identify some of the birds or animals in his area will hardly be assisted by learning that bee eaters or bandicoots are to be found there, unless he already happens to know what these are like. *The Pacific World*, in short, is a primer likely to be more interesting to Americans at home than useful to those already in that area.

SCIENCE YEAR BOOK OF 1944.

By John E. Ratcliff. Doubleday, Doran and Company, Garden City, New York. $2.50. 8¾ x 7¼; xxxi + 218; 1944.

This collection of articles from popular magazines shows scientific writing for the layman at its best, readable, reliable, dealing with outstanding recent achievements. The compiler is to be highly commended in his selections. He has, moreover, contributed an interesting introduction that sets a general background for the selections, discusses the benefits we will derive from war research, and points out the relationships of research to social and economic problems.

The selections are grouped in four parts, dealing respectively with medical research, physics and chemistry, agriculture and nutrition, and aviation and other sciences. In the first group one may read the story of penicillin, or about caudal analgesia for painless childbirth, the treatment of war casualties in the front lines, new and better anesthetics, Dr. Orr's plaster treatment of compound fractures and the Stader splint, influenza and new methods of fighting it, dicoumarin for preventing post-operative blood-clots, or cheap photofluorography for mass examinations in the detection of tuberculosis. Part II discusses electronics, radar, the betatron, static electricity, and the uses of the gyroscope. Part III tells of the introduction into the Americas of new strategic crops, Hevea for rubber, cinchona for quinine, abacá for Manila hemp, derris for rotenone, and many others; of the rapidly increasing use of artificial insemination in dairy cattle breeding; of the transport of vital seeds and insect enemies by air; of the K ration; of histamine and its relation to allergy; and of the detection of riboflavin deficiency by observations of the development of blood vessels in the cornea. Part IV, besides accounts of the helicopter and the use of gliders, of the house of tomorrow, of long-range weather forecasting and the study of the stratosphere, includes two articles of additional biological interest: one on the physiology of falling; the second on the phenomenon of cycles of weather, of animal populations, of diseases, and of business prosperity.

It is greatly to be hoped that Mr. Ratcliff will be able to continue these annual volumes on the high plane of this one.

YOUR WORLD TOMORROW.

By Donald G. Cooley and editors of Mechanics Illustrated. Essential Books, Inc.; Duell, Sloan and Pearce, New York. $2.50. 9¼ x 6½; 252; 1944.

There is an undoubted fascination in attempting to look into the post-war era and examine the changes that may, with reasonable assurance, be predicted in our ways of life. Donald G. Cooley has had ample experience in science-writing for the layman and displays the cars, trains, houses, and gadgets of the future in the vigorous superlatives of the super-salesman. Will any wife whose husband can afford a "packaged" kitchen and an "electronic cabinet" equipped to provide radio, television, phonograph, recording, and movies ever again leave home? Well, just take a glance at this new plastic car or this "amazing helicopter" or this "amphibious jeep" and get your answer! There is something exciting on every page of this book. It should be taken only in minimum doses.

Most of the delights of the future appear to be mechanical, chemical, or electronic devices. However, there are advances in the biological realm, too, that will affect every man's life. To aid in the combat against disease one may call upon the cyclotron to make artificially and temporarily radioactive substances, upon electron microscope and more powerful x-rays, photography of fluoroscope images, ultraviolet sterilamp, pollen-filtering precipitron, sulfa drugs, penicillin, blood plasma, and new anesthetics. Dehydrated, concentrated, and frozen foods will be abundant. New foods, such as edible yeast and sugar synthesized from sawdust, will titillate tomorrow's palate. "Tomorrow's farm is going to be different." Eggs may have green, red, or blue yolks. New plant strains, resistant to disease and many times more productive than those grown today, seedless fruits and melons, and new crops grown to support new industries, such as oils and plastics, will transform agriculture. The use of plant hormones and other growth regulators, the action of x-rays in producing valuable mutant forms, the provision of abundant and cheap fertilizers, and the improvement in quality of domesticated animals through artificial insemination will combine with improved farm machinery, long-range weather forecasting, and mechanical cottonpickers to make it "not only . . . profitable to live on tomorrow's farm—it will be fun!"

If one is to judge from the predictions of biological advances, the author has been relatively conservative as a seer. Most of them have already been realized, if not yet put into general practice. The ultimate comment on all such essays of imagination is, however, to be found in a cartoon in THE NEW YORKER of September 9, 1944, p. 23, q.v.

CARNEGIE INSTITUTION OF WASHINGTON YEAR BOOK *No. 42, July 1, 1942–June 30, 1943. With Administrative Reports through December 7, 1943.*

Carnegie Institution of Washington, D.C. $1.50 (cloth); $1.00 (paper). 10 x 6½; xxxii + 208; 1943.

In addition to the lists of personnel associated with the Carnegie Institution in various capacities, the organization, plan, and scope, the articles of incorporation, and the by-laws of the Institution, the present yearbook includes the report of the executive committee, the report of auditors, the report of the president, and the reports of the various departmental activities.

In the report of the president, emphasis is placed upon the activities of the Institution in relation to the armed services, its contribution to the war effort, and the confidential nature of the majority of the research projects undertaken in the past two years. The general trend of the Institution in diverting its activities from the field of pure science to that of

applied science in the prosecution of the war is, in the opinion of the president, a noteworthy accomplishment, but there is a strong plea for reverting to the fundamental sciences when the war is over.

The heavy demands of the war upon the Astronomy and Terrestrial Science Departments, not only for the performance of important research work, but also for the technical skills of highly trained personnel, has greatly curtailed the peacetime activities of these two departments. However, several solar and stellar investigations have continued in progress, and the important findings are reported here.

The reports from the various divisions and departments of the biological sciences cover such pertinent subjects as: the biochemistry of the algae; experimental taxonomy as applied to the grasses; standardization of the developmental stages of the human embryo; the physiology of the mammalian fetus; hormones related to the reproductive organs; the gene; polyploidy; and anthropology as related to human genetics.

The report from the Division of Historical Research summarizes the activities of the division for 1942–43 and presents an interesting paper on "Paleontology, Early Man, and Historical Geology," by John C. Merriam, President-Emeritus of the Institution.

An index covering topics and authors is provided.

GEOLOGY IN THE SERVICE OF MAN. *Pelican Books. By W. G. Fearnsides and O. M. B. Bulman. Penguin Books, Harmondsworth, England; New York.* 9d (paper). 8 x 5¼; 158; 1944.

This addition to the Pelican Series is an excellent, if highly condensed, survey of economic geology. There are five introductory chapters on the principles of geology. These will serve the purpose of any biologist who wants a general understanding of earth materials and their changes, of diastrophism, weathering and erosion, and the modifications of topography. There is a brief sketch of Britain's geological history, which ignores paleontology almost completely, and a chapter on the interpretation of geological maps. In Part II, "Some Applications of Geology," the chapters on the geology of soils, of petroleum, and of coal will especially interest biologists. The extraordinary degree of condensation is evident from the devotion of only six pages to petroleum geology, only seven to coal, and only three to iron! The authors are to be highly complimented on producing well-rounded treatises of such brevity. However, one should be warned that apparently much is expected from the British layman in the way of technical vocabulary and background in chemistry. This is no book for the easychair even if made for the pocket.

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